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Contents.

	PAGE
The Provision of Industrial Capital	421
A Clean Start	421
Correspondence	422, 442
Iron and Steel Production	422
Random Shots	422
Malleable Castings	423
Catalogues Received	426
Electric Power in the Foundry	427
The New Kryn and Lahy Concern	427
British Facilities for Foundry Training	428
The Future of Alloy Cast Iron	430
Institute of British Foundrymen	430, 438
Aluminium Casting Alloys	431
Theory or Practice in Grey-Iron Foundry	433
Birthday Honours	435
Variables in Steel Foundry Practice	436
Trade Talk	440
Personal Paragraphs	440
Contracts Open	440
Reports and Dividends	440
New Companies	440
Iron and Steel Markets	442

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Forthcoming Events.

JUNE 20-23.

The Newcomen Society for the Study of the History of Engineering and Technology:—Summer meeting at Stourbridge.

Institute of British Foundrymen.

JUNE 12-15.

Annual meeting and conference at the Association Hall, London Road, Leicester.

The Provision of Industrial Capital.

It is a distinctly surprising phenomenon that at the present time, when many sections of industry are still in a condition far from healthy, there is yet more capital available than can profitably be utilised. The most casual observer of the daily press can hardly fail to have been struck by the large number of new companies being floated, and it is a fact that practically every issue offered to the public at the present time is over-subscribed within a few hours. Cases have even been known where a list has been opened at 9 a.m. and closed, fully subscribed, by 10.30 or so.

Where is the money coming from? A certain section of the public is undoubtedly suffering from a craze for speculation on margins, which in itself is not especially healthy, although we believe its victims to be chiefly those who can afford an expensive hobby or two. But it is of greater importance to recognise the rise to prominence of the small investor—the man who desires security for his strictly limited savings, and to whom the dividend is of more account than capital appreciation.

The development follows more or less logically upon the rise of the small property-owner. The post-war years have seen an almost complete change-over from renting to ownership where houses are concerned. This applies to all grades, but especially to the better-class artisan and the lower middle-class—as witness the innumerable arrangements for purchase of houses of the "subsidy" type, all well under £1,000. The result has been in effect to create a large body of small capitalists, and it may be that ownership of capital in this form has served as an inspiration and an encouragement to the ownership of capital in other forms. This suggestion is borne out by the rise of the Building Societies, whose recent growth has been enormous, and also by that of the Friendly Societies and the Insurance Companies—endowment insurance being in fact an important class of investment.

What it means is in effect that industrial capital is no longer to be sought exclusively at the hands of the big man, since the recent trend of events has made it sufficiently obvious that in spite of motor-cars and cinemas the small man has a margin which he is able and willing to invest under conditions of reasonable security.

This is well worth the consideration of an industry like iron and steel, where, although the Joint Stock form has in fact been generally adopted, it is in many cases nothing but a form, the shares remaining largely in private hands and never coming on the market at all. An industry so organised can have no means of tapping this new and valuable source of capital, and this seems doubly unfortunate, since on the one hand the money is needed and on the other it is going begging. In fact, what is badly needed is some means of directing surplus small savings into the channels that are nationally most desirable.

A Clean Start.

In our correspondence column Mr. John Shaw makes a reasonable and reasoned attack upon the views we expressed last week. These views were outlined to show that research based on the utilisation of the purest materials (American washed or Swedish white iron, if thought desirable and sufficiently pure) was essential to industrial progress and complementary to work initiated on alloys more nearly imitating everyday practice. To this attitude we still most strongly adhere, on the following grounds:—Academic research has furnished the whole nomenclature of the subject—defective though it is to our mind; it has brought to light every constituent, except sulphur, so far found as existing in cast iron; the recent developments in cast iron invented by persons familiar with the theory of ferrous materials; the vast improvement in the mechanical properties of cast iron during the last quarter of a century are contemporaneous with theoretical knowledge, although the material has been in existence hundreds of years.

From the ironfounder's point of view steel is a very pure material, but to the metallurgist handling that alloy it is definitely impure. Not all steel alloys can be placed with alacrity on the non-carbon equilibrium map. They, too, have their compounding difficulties, and differences are noted when constituents are introduced as elementary substances or as alloys. Many of the modern steels contain less iron than cast iron and a larger number of other elements, yet many of the "steel" metallurgists are clamouring for work to be carried out on purer materials than hitherto, in order that explanations may be forthcoming of the complex properties of commercial steels. Mr. Shaw pleads that constant reference to steel is not likely to help greatly in understanding cast iron, but as malleable iron has demonstrated by its close approximation to the former alloy hope is always prevalent that this type of metal will be produced by direct fusion. This analogy with steel is an irreplaceable incentive to further effort, and intense research will clear up the discrepancies in behaviour attributable to the presence of graphite and the extra impurities.

XUM

Correspondence.

[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]

Where to Start?

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—I have read with interest and, dare I say it, with some amusement, your Editorial concerning the recent Paper I gave to the Sheffield Branch and the American Foundrymen. It is so essentially the academic view that ignores demonstrated facts, unless from a foreign source, and clings to its small scale investigations with so-called pure materials. The Paper is not an attack on scientific methods, or results obtained by the means mentioned. These are accepted as being correct under the conditions specified. The known carefulness and attainments of the investigators forbid any other conclusion. But it is a definite attack on the use of a pure washed iron with concentrated additions of other elements added, and calling the resultant material cast iron, or expecting a furnace iron to behave in the same manner and give similar results. It is also a plea for a standardised method of attack, so results are comparable. Take the well-known investigations on the effect of silicon and arrange them in their progressive silicon content. Then note the combined carbon:—

	Si.	T.C.	C.C.	Size of bar.	Tensile.
	Per cent.	Per cent.	Per cent.		Tons.
Coe	0.4	3.22	3.19	1 in. sq.	14.33
Hamasumi ..	0.64	2.93	1.13	1½ rd.	18.4
Hague ..	0.66	2.95	2.82	1 in. sq.	—
Coe	0.80	3.04	1.27	1 in. sq.	10.06
Hamasumi ..	1.18	3.30	0.9	1½ rd.	10.07
Hatfield ..	1.68	2.95	2.3	1 in. × ¾ in.	11.41
,, ..	1.72	3.07	0.6	1 in. × ¾ in.	12.70
Hague ..	1.95	2.47	0.97	1 in. sq.	—
Coe	2.03	2.9	1.08	1 in. sq.	13.7
Hamasumi ..	2.9	2.9	0.64	1½ rd.	16.5
,, ..	2.9	3.35	0.66	1½ rd.	7.44

Can anyone estimate the effect on their casting of a small addition of silicon from these results? Yet this is the position after 25 years of research. The pure iron base and small scale investigations have been found successful in steel because the reactions are similar. You have a practically pure material in both cases. The additions are made with concentrated alloys in each case. Therefore, the result may be expected to be somewhat similar. With cast iron there are entirely different conditions. The other elements form a much larger proportion of the metal; time and temperature are vital factors. There is no doubt many of the conclusions drawn when using a pure iron base do not agree with those when straight furnace metal is used. The additions of concentrated elements give a different result than straight pig-iron of a similar analysis. There are a number mentioned in the Paper, and these could be multiplied by the dozen. Recently the results given in a Paper by those careful workers, Drs. Hanson and Everest, confirm this. They state Series P3 with 1.2 per cent. Si, 3.5 per cent. C, and 1.2 per cent. P was quite unmachinable on a bar 1½ in. × 1 in. section. While one accepts this statement as true for their conditions, it does not apply to ordinary cast iron. The following bars, 2 in. × 1 in. from MacKenzie's Paper, show how little effect this has:—

T.C.	Si.	Mn.	S.	P.	C.C.	Brinell.
Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
2.96	1.24	0.42	0.048	1.55	0.91	262
3.64	1.29	0.54	0.054	1.51	0.79	228
3.00	0.90	0.46	0.146	3.55	0.56	277
3.78	1.17	0.34	0.061	1.14	0.88	248
3.42	1.19	0.37	0.067	2.25	0.87	286
3.50	0.84	0.42	0.113	2.01	1.09	269
3.25	1.29	0.38	0.049	1.07	0.70	248
3.26	1.26	0.38	0.02	2.09	0.79	277

The same authors' (Hanson and Everest) own figures giving the analysis of pure irons and refined irons show the same difference. Here with consistently lower carbons and silicons in the refined irons, the C C is at least one-third lower than in the synthetic irons. With the highest Phos. there is an actual drop in the C C, a result in keeping with ordinary practice:—

	Synth. iron.	Ref. iron.	Synth. iron.	Ref. iron.	Synth. iron.	Ref. iron.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
T.C.	3.50	3.05	3.50	2.98	3.50	2.90
C.C.	1.17	0.78	1.18	0.81	1.22	0.74
G.C.	2.33	2.27	2.32	2.17	2.28	2.16
Si.	2.40	1.87	2.48	1.77	2.61	1.71
Mn.	Trace	0.74	Trace	0.70	Trace	0.67
S.	0.03	0.09	0.03	0.90	0.03	0.08
P.	0.18	0.24	0.48	0.51	1.27	1.16

With regard to the binary and ternary diagrams mentioned, one accepts at once their usefulness as regards steel, but it is evident there is a limit to conclusions drawn from them for cast iron, with its larger amounts of other elements, equilibrium being seldom, if ever, reached, and no after-heat treatment as in steel and malleable. I deny your premises Nos. 1 and 2, "That by these diagrams you can establish the correct possible composition, etc.," otherwise why has it not been done? The most important of the diagrams have been in existence since 1912, yet, according to one leading authority, the only vital advance during the last decade has been made from investigations using a cast-iron base and using ordinary methods but completely controlled.

Even your "Pointer" concerning high silicon is wrong under certain conditions as the following taken from Maurer's results (FOUNDRY TRADE JOURNAL, December 29, 1927) shows all the high silicons were abstracted in one table and all the high total carbons in the second:—

T.C.+Si.	T.C.	C.C.	G.C.	Si.	Mn.	P.	S.	Tensile.	Brinell.	
Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Tons.		
5.9	2.65	0.78	1.88	3.24	0.9	0.17	0.08	14.5	158	High Si.
4.45	3.65	1.27	2.38	0.95	1.0	0.23	0.06	11.34	132	High car.

So that with a silicon of 3.24 per cent. one obtains a higher tensile and Brinell with a lower combined carbon. It is evident in this case the low total carbon is of more importance than the high silicon, the higher graphitic carbon lowering both tensile and Brinell in the higher carbon series. I wish to state again, this Paper was written as a criticism of scientific investigation. Our knowledge would not have been in its present position but for the painstaking efforts of these workers, but that very knowledge has shown us that certain snags must be taken care of. The fact that many metallurgists fail to appreciate is that the results found from the investigation of two elements may differ entirely if a third element is added to the mix, and even then the results may vary due to the manner in which the third element is added, whether in a pure state or already in combination with one of the elements in question, of which the desulphurising action of manganese is an outstanding example. It needs to be remembered that no combination of two elements warrants statements as to their effect when alloyed with at least three others.—Yours, etc.,

J. SHAW.

2, Parkstone Avenue, Southsea.
June 8, 1928.

Iron and Steel Production.

The National Federation of Iron and Steel Manufacturers in their Statistical Bulletin for April state that the production of pig-iron in April amounted to 555,000 tons, compared with 592,600 tons in March and 680,000 tons in April, 1927. The daily rate last April was thus 18,500 tons, compared with 19,116 tons in March. There was a net decrease of one furnace in operation at the end of the month, three furnaces having been blown in and four furnaces having ceased operation. The production of steel ingots and castings last April amounted to 644,100 tons, a decrease of 149,200 tons compared with March, the decrease being rather more than can be accounted for by the Easter holidays.

Random Shots.

So the Institute of Metals is to be the next to visit America, and that in the not too distant future of 1932! Not the least welcome feature of the announcement recently made to this effect is the news that arrangements are if possible to be made for an inclusive fare of £100 for a five weeks' trip—by no means an exhorbitant figure, as those who are in the habit of visiting the States will readily agree. To some of us, however, even £100 seems quite enough, and we can only find consolation in the fact that 1932 is still a good way off, and there is time for all sorts of things to happen, including a reduction in the income tax. . . . .

* * *

And, incidentally, a bright idea has just struck me—why doesn't the Institute of Metals—and for that matter, any similar body contemplating such a trip—encourage members to save for the purpose by taking a leaf out of the Post Office book, and distributing "Home Safes," the contents to be offset against the cost of the trip in due course. . . . .

* * *

But the real difficulty about these affairs is that the wife always wants to go too! Not, perhaps, an unreasonable desire—nor would we for a moment be so churlish as to suggest that we would prefer to leave our ladies behind on such an occasion. But it remains a very real fact that where a single man might be able to afford £100 for a trip combining business and pleasure, especially if his firm or organisation bear some part of the cost, a married man has to think twice about it if it means paying for his wife as well. . . . Especially as the lady will be quite certain to need special—and not improbably expensive—clothes for the occasion. . . . . .

I have been studying with interest the broadsheet published by an American confrère of our own during the four days of the A.F.A. convention in Philadelphia. Such publications are a typically American idea, and I doubt whether they would fit in too readily with our own conditions. But I cannot help being struck by the possibilities of the method as an alternative to the inquiry-desk-and-notice-board scramble that characterises so many conferences on this side. How far the publication in question is in fact utilised for the dissemination of vital information I don't know—but surely it has considerable possibilities in this direction. . . . .

* * *

As a matter of fact I was chiefly struck by the comparatively serious tone of the paper. It is, of course, full of "pep," and as bright and lively as one could wish, in the typically American style. But there is very little material of a definitely entertaining description—a surprising fact in view of the large quantity of humorous material that technical journals in the States usually seem to carry.

* * *

I have, however, gleaned the following gem, ascribed to a certain Mr. Jim Mackenzie of the American Cast Iron Pipe Company. It is the story of a coloured lady from Birmingham, Alabama, who came off badly in a divorce suit there. "Dey ain't no justice in dese yeah co'ts no mo'," she complained bitterly. "Dat dey man gits de house, he gits de divo'ce, he gits de money. All ah gits is de'leben chillens an' dey ain't none of 'em his'n!"

* * *

Arising out of last week's Aberdeen story, I was pleased to see (in the "Radio Times" as a matter of fact, so presumably it is authentic) that all the egg-shells from Aberdeen are now sent to Savoy Hill to be relayed!

MARKSMAN.

Malleable Castings.*

By W. T. Evans and A. E. Peace.

The preparation of a Paper on malleable castings to be put before European foundrymen presents difficulties which would not arise if only one class of material had to be considered such as is the only product of malleable foundries in America, viz., black-heart, in the production of which the authors are now actively engaged. Having had experience of both European and American malleable it is hoped to give some idea of the general production of the two varieties, as many features are common to both.

It is generally known that Reaumur commenced the production of malleable castings in Europe somewhere about the year 1722, and that Boyden, who emigrated to America from England, in attempting to make Reaumur malleable with the American pig-irons, obtained results, about 1826, which were the foundation of the present black-heart process. The manufacture of castings by this latter process has been in operation in Europe for over 50 years, using chiefly American pig-irons, but now excellent results are being obtained by the use of all British irons, which can be bought to as close specifications as American irons provided the pig-iron is ordered in large enough quantities to enable manufacturers successfully to control the burden of their blast furnaces.

There can be no doubt that malleable castings in Europe have been something of a bogey to the engineer, owing to a non-uniformity of quality, and in particular with regard to indifferent machinability which under present-day conditions is a most serious matter, owing to the expense of mass production tooling operations. This fact is emphasised by the latest B.E.S.A. specification for malleable which includes a clause to cover a minimum speed for machining.

In this Paper the authors will endeavour to convince engineers and users of malleable castings that a reliable product from both black-heart and white-heart varieties can be, and is being, produced by the application of correct methods.

Basic Differences.

The authors feel that before going into the details of manufacture it would be advisable briefly to describe the two classes of material.

White-heart, or Reaumur, castings are usually produced from metal melted in the cupola or crucible from pig-irons of a grey mottled or white fracture, the mixture of which, with the necessary scrap, is controlled to obtain castings of a white fracture free from graphite. The following gives some indication of the analysis of the castings as poured:—T.C., 3.0 to 3.5; Si, 0.5 to 0.8; Mn, 0.10 to 0.40; S, 0.20 to 0.45; and P, 0.06 per cent.

The melting of metal for black-heart castings is carried out in acid open hearth, air furnace or electric furnace, the use of the cupola not being satisfactory. Pig-irons used are of grey hematite quality, which, together with scrap and sprue, are blended to produce a graphite-free casting, similar in fracture to the white-heart casting, but of a very different composition, as is shown by the following analysis:—T.C., 2.30 to 2.70; Si, 0.7 to 1.00; Mn, 0.25 to 0.35; S, 0.03 to 0.08; and P, 0.20 (max.) per cent. It will be noticed that the chief differences in composition of the two malleables are the lower T.C. in the black-heart and the much higher percentage of sulphur in the white-heart material. Reference will be made to these in greater detail later.

White-heart castings are annealed in an oxidising packing of hematite ores at a temperature of approximately 980 deg. C., for a period at the highest temperature of about 100 hrs. Black-heart annealing is carried out with no oxidising packing at a temperature of around 850 deg. for a period of 60 hrs.

The common names of the two varieties have arisen from the appearance of the fractures of the annealed castings. The white-heart when fractured shows a dull grey skin merging rather sharply into a bright crystalline centre or core. The skin consists of decarburised iron which progressively increases in combined-carbon content to the centre where the structure is a pearlitic matrix with, frequently, free cementite, and some free carbon nodules. (See micro-graphs, Figs. 1 and 2.)

The fracture of annealed black-heart is uniformly black throughout except for a slightly lighter appearance on the extreme edge. The structure is ferrite with rounded nodules of free carbon (temper carbon) distributed throughout. (Fig. 3.)

The B.E.S.A. specifications Nos. 309 and 310 indicate the physical properties of the two types, and a portion is here abstracted:—

Ultimate Tensile Strength (minimum)	White-heart 20 tons.	Black-heart 20 tons.
Elongation in 2 in. (minimum)	5 per cent.	7½ per cent.
Bend. Cold, Round 1 in. rad. (minimum).	45 degrees.	90 degrees.
Machineability. Approx.	90 ft. per min.	—

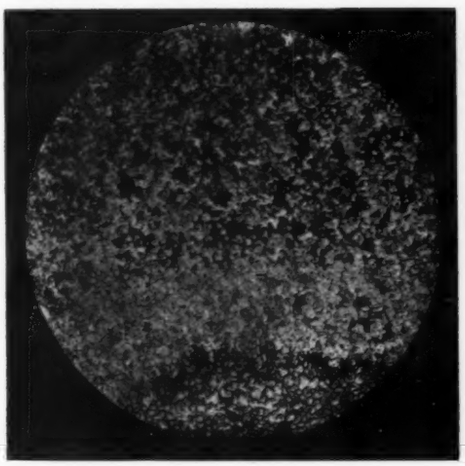


FIG. 1.—RIM OF ANNEALED WHITE-HEART. ETCHED × 50.

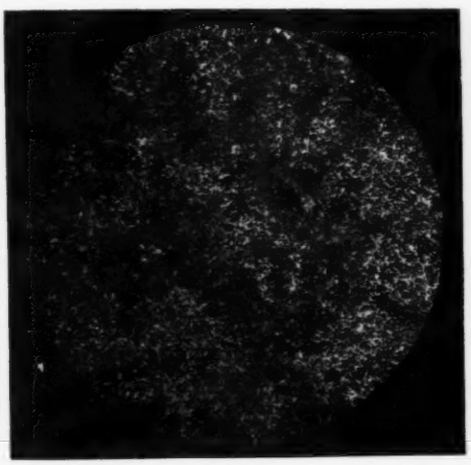


FIG. 2.—CENTRE OF ANNEALED WHITE-HEART. ETCHED × 50.

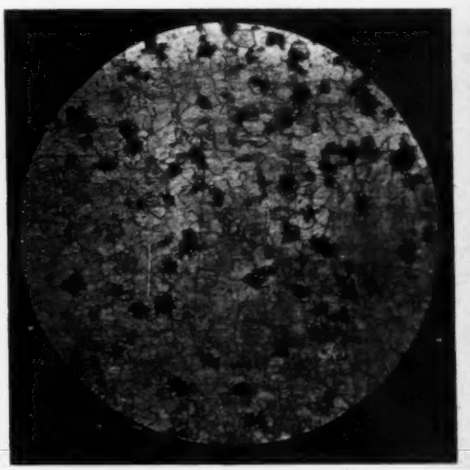


FIG. 3.—ANNEALED BLACK-HEART. ETCHED × 50.

MANUFACTURE.

Air Furnace Melting for Black-heart.

The air furnaces used have capacities ranging from 5 to 30 tons and typical furnaces are illustrated in Figs. 4 and 5. The furnaces are lined with good-quality firebricks which have to stand temperatures around 1,600 deg. C., and resist the action of a slightly oxidising slag. Aluminous

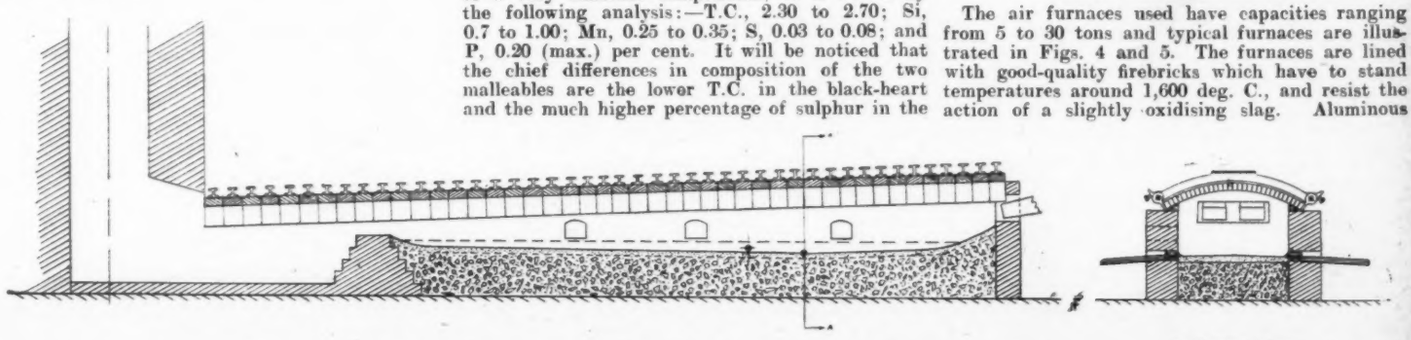


FIG. 4.—PULVERISED-FUEL FIRED AIR FURNACE. 20 TONS CAPACITY.

* A Paper presented to the Leicester Convention of the Institute of British Foundrymen.

bricks excel in withstanding the high temperatures and erosion, but exhibit unwelcome spalling propensities, owing to the rapid cooling of the furnace when a heat is taken off and another one charged. Table 1 shows the life of various bricks in the walls.

TABLE I.—*Life of Various Refractories in Air Furnace Walls Using Pulverised Fuel.*

Analysis.	Firebrick Good Quality.	Aluminous Brick.
SiO_2	63.90	47.62
TiO_2	1.12	3.80
Fe_2O_3	2.20	1.34
Al_2O_3	29.73	44.58
MgO	0.46	0.25
CaO	0.88	1.10
Alkalies	1.71	1.31
Melting Point ..	1700°C.	1780°C.
Life Average Number of Heats.	13	17

Silica sand is generally used for making the bottom of the bath, but firebrick bottoms have been adopted in some cases with success. The advantage of the latter type of bottom is the saving of fuel required to frit or burn a bottom in. A sand bottom will last about 8 or 9 heats, whereas a brick bottom with care may run to 5 or 6 times this life, which means a direct saving of 80 per cent. of the fuel and time for fritting.

In laying a brick-bottom, joints about ⅛-in. wide are left between the bricks, and a space of 2 in.

TABLE II.—*Life of Refractories in Air Furnace Bungs Using Pulverised Fuel.*

Analysis.	Good Quality Fire Brick.	Aluminous Brick.	Sillimanite Brick.
SiO_2	59.40	49.34	36.35
TiO_2	0.79	2.00	2.13
Fe_2O_3	4.97	2.10	2.34
Al_2O_3	32.78	43.56	58.02
MgO	0.96	0.45	0.06
CaO	0.60	1.01	0.60
Alkalies	0.50	1.54	0.50
Melting Point deg. C.	1680	1740	1800
Life Average Number of Heats	27	30	25
Causes of Failure	Erosion	Chiefly Spalling.	Spalling.

or so, where the bricks meet the side walls, is rammed up with dry grog, prepared from used firebricks, which is also run in loosely between the joints. This procedure is sufficient to prevent the bottom cambering when expansion of the bricks takes place.

The roof of the furnace is made of loose arches braced by cast-iron or steel frames, which can be adjusted to take care of the expansion and contraction of the bricks. The requirements of firebricks for these arches or bungs are ability to withstand the cutting action of the flame at high temperatures and the rapid change in temperature occasioned after tapping a heat and recharging. The life of the bungs is around 27 heats, but those which are continually being removed for charging the heat give a much shorter life, owing to the disturbance of the joints and to the rough usage. Table II shows the bung life obtained from various qualities of bricks.

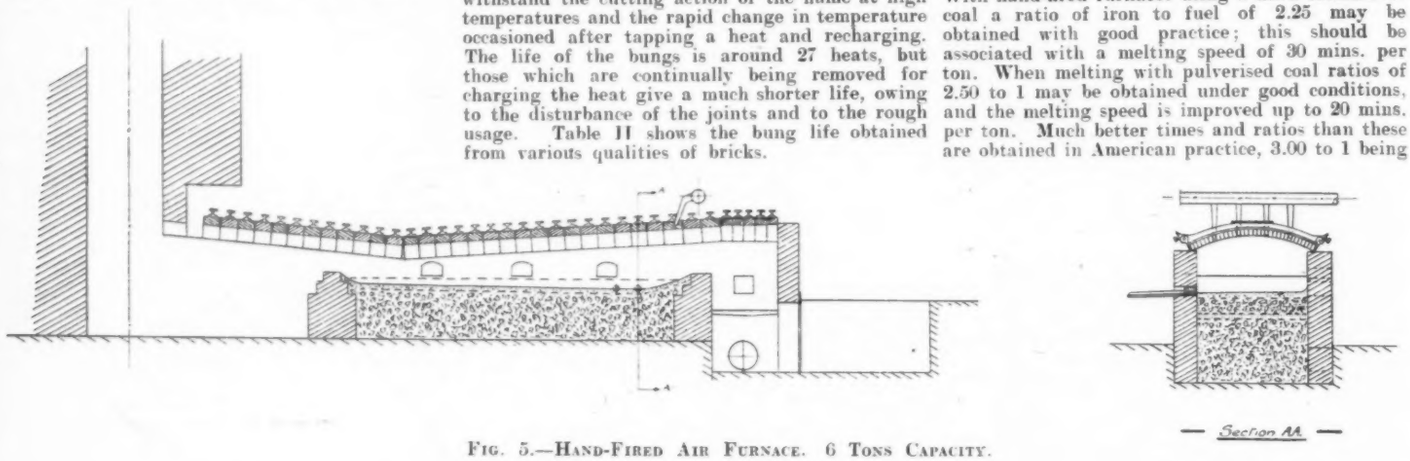


FIG. 5.—HAND-FIRED AIR FURNACE. 6 TONS CAPACITY.

Conditions Influencing the Life of Refractories.

One of the chief factors which determines the life of refractories is the velocity of the flame passing through the furnace, and with furnaces working on pulverised fuel the secondary air should not be admitted to the furnace at a pressure above 2 oz. Burners and pipe lines are designed of sufficient area to supply the correct volume of air at this low pressure. Dry coal and low velocity are the first essentials for the successful application of pulverised coal.

With hand-fired furnaces air is admitted below the fire grate in such quantities as partially to burn the coal with a distillation of the volatile products, and pass into the furnace what is virtually a low-grade producer gas. The secondary air, which is admitted through tuyeres in the roof, effects combustion of this gas in the furnace. The pressure of the primary air under the firebars must be so regulated as not to blow any of the small coal over the front bridge on to the bath. This happening usually termed "throwing ashes" increases the carbon content of the bath and is often caused by using friable coals.

The Bath.

It will be observed from Figs. 4 and 5 that the roof is built with a straight taper from burners or firebox to bridge. The bath of metal may be from 5 to 9 in. in depth at the deepest part (lower taphole), depending on the capacity of the furnace: too deep a bath lengthens the time required to obtain the necessary casting temperature. Tapholes are usually put in at two levels, the lower to drain the bath and the higher one to take off the hottest metal first. These holes are better made with a special brick, such as is shown in Fig. 6. Frozen tapholes can be easily opened out with an oxygen torch; that is, a length of iron piping ½ in. dia. coupled to an oxygen cylinder, gas being delivered at about 30 lbs. pressure.

Charging Operations and Fuel Ratios.

When charging a furnace two or three bungs are removed at the front and at the back of the furnace. The scrap and sprue are first charged and levelled down, following with the pig-iron and steel scrap; the bungs are replaced and luted up. With hand-fired furnaces using a hard bituminous coal a ratio of iron to fuel of 2.25 may be obtained with good practice; this should be associated with a melting speed of 30 mins. per ton. When melting with pulverised coal ratios of 2.50 to 1 may be obtained under good conditions, and the melting speed is improved up to 20 mins. per ton. Much better times and ratios than these are obtained in American practice, 3.00 to 1 being common, and the authors have seen heats made with a 4.0 to 1 ratio. There seems no doubt that these excellent figures are obtained by reason of more easily dried fuel. The composition of suitable American and English coals is compared in Table III.

In connection with fuel ratios it should be borne in mind that they vary considerably with the size of the heats which can be melted, which factor is determined by the class of castings being produced, as one day a single large heat may be run and another day two smaller heats may be necessary to clear the floor space.

Test Plugs.

With pulverised-fuel furnaces, the charge is not touched for from two to three hours, by which time the flame will have levelled it down. The removal of slag from the molten bath assists in raising the temperature of the metal into which the furnaceman pulls down any piles of unmelted iron. Complete fusion is then quickly obtained, and slagging proceeds until the surface of molten metal is practically clear. If the temperature of the bath is judged to be high enough, tests are taken with a sampling ladle. The authors have adopted the practice of casting test plugs in cores made from ordinary oil-sand mixtures. This has been standardised to overcome the variation of speed of solidification and further cooling, which is seriously affected by using green sand, which may be either dry or, on the other hand, very wet. It will be seen from Fig. 7 that a notch in the lower half of the plug is made, which ensures a fracture in the same position every time. After a test plug is poured it is left in the core until set. It is then cooled off by inverting it and immersing the upper end in a trough of running water arranged to give a standard depth of immersion of approximately 2 in. Thus by placing the bars vertically the portion eventually to be fractured is not unduly chilled by contact with the water.

The taking of tests is proceeded with at 15 min.

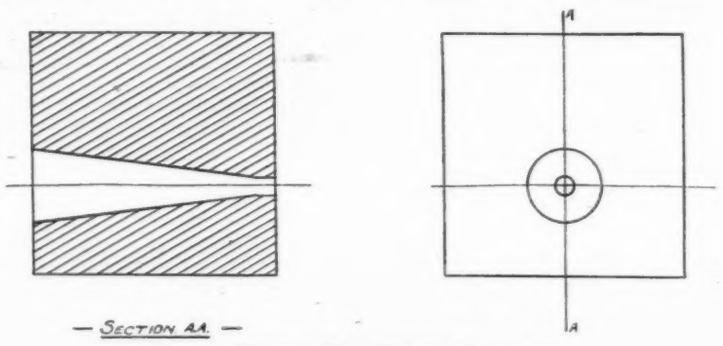


FIG. 6.—TAPPING HOLE BLOCK. SCALE 1/6.

intervals until the fracture of a slaked test is judged to be evidence that the bath has attained the desired composition for tapping. With good melting practice two or three tests will meet the requirements, and by this time the bath will be hot enough for casting. The illustrations comprising Fig. 8 show fractures of test plugs, with analyses appended, which are representative of the progress of a heat.

TABLE III.—*Analysis of Coals Suitable for Malleable Air Furnaces.*

	Suitable for Hand Firing.				Suitable for Pulverised Firing.			
	English.		American.		English.		American.	
	1	2	1	2	1	2	1	2
Moisture.	7.06	5.96	0.62	1.10	8.20	9.04	1.53	1.35
Proximate Analysis on Dried Sample { Volatile Matter	31.73	32.46	35.63	33.95	33.18	35.69	32.02	33.64
Fixed Carbon	63.40	59.53	58.32	60.68	59.83	58.72	60.58	58.26
Ash	4.85	8.06	5.43	4.27	6.99	5.59	7.40	8.10
Sulphur	0.35	0.84	0.70	0.45	0.84	0.62	0.61	0.61
Calorific Value B.T.U.s. ..	13,900	11,580	13,902	14,276	13,301	13,755	13,856	14,027

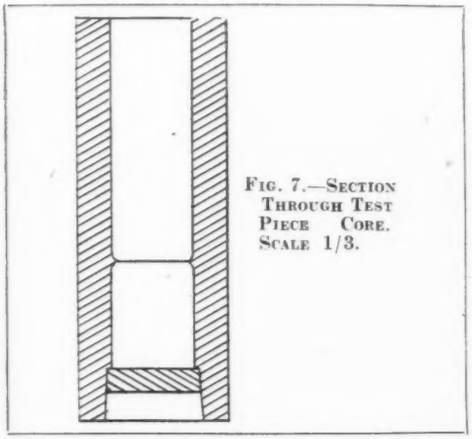


FIG. 7.—SECTION THROUGH TEST PIECE CORE. SCALE 1/3.

This method of tapping by fracture a border line iron which is only permitted a small range of chemical variation may seem, in the light of present-day cast-iron criticism, somewhat crude, but when it is considered that out of some 12,000 heats poured, with an aggregate tonnage of approximately 100,000 tons, only six failed to produce satisfactory material for annealing, one has to admit that this practice is perhaps equal to the more scientific methods so much advocated.

Recording Data.

Regularly recording the details of furnace working is very useful. Fig. 9 shows the recorded data on one month's operation of a furnace. As S and P are subject to little variation, only TC, Si and Mn are entered. It will be seen that the information summarised includes weight of charge, time of melting, weight of fuel used and melting ratio, additions made, number of tests taken, important repairs and the furnaceman's check number.

Adjustments to Composition.

The number of tests, and the appearance of the fractures, together with the analytical and other data from the particular mixture and previous heats on the furnace in question, enable those in charge of the melting operations to decide whether any additions of carbon, silicon or manganese are necessary. These are added to the bath in the form of crushed, hard coke, 45 per cent. ferro-silicon and 80 per cent. ferro-manganese, and are put up in standard quantities equal to definite percentage additions per ton of melt.

An ideal composition for the hard iron is TC, 2.35; Si, 0.85; Mn, 0.28; S, 0.05, and P, 0.20 per cent. (max.), and mixtures are used and operated to obtain this anlysis. The loss of carbon, silicon and manganese on melting varies with each furnace and with other factors, such as slight alterations occasioned by repairs. It will therefore be seen that separate mixtures should be made for each furnace and frequently adjusted to take care of the slight changes in melting loss. It is sometimes advisable to change the mixture, apart altogether from analytical considerations, as the fluidity and life of the iron may not be all that is desired.

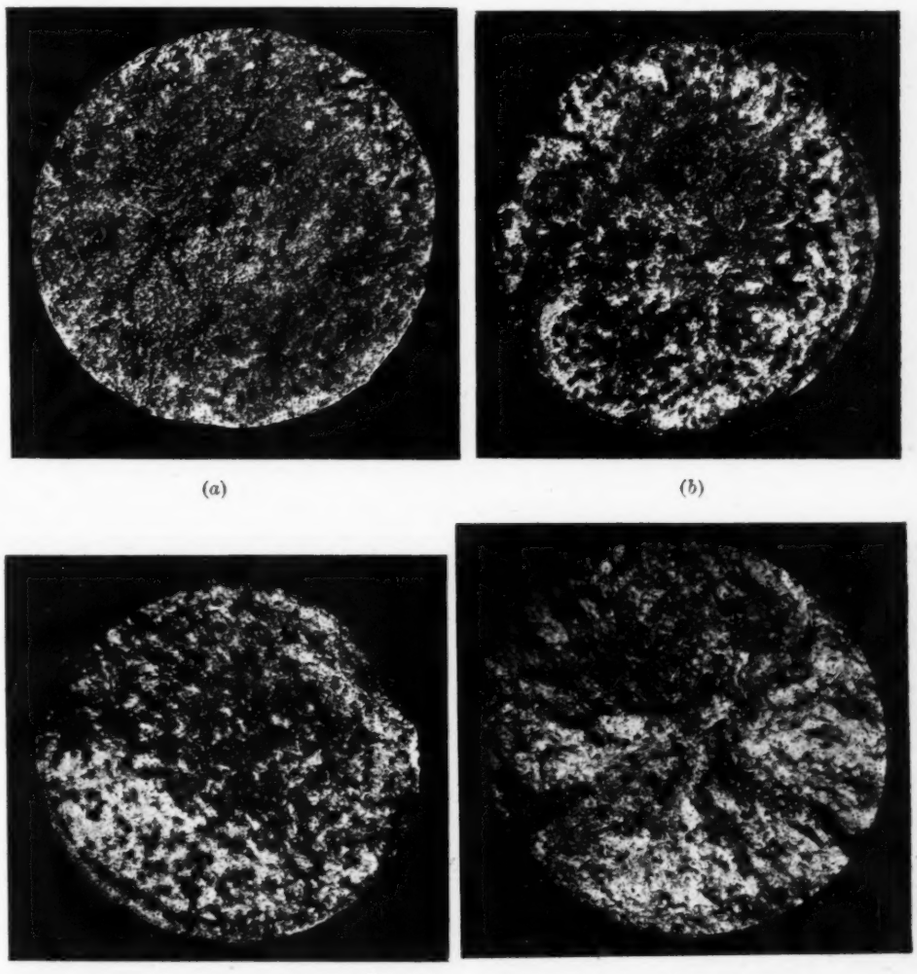
Losses Sustained.

Typical losses are TC 0.80, Si 0.35, and Mn 0.20 per cent. Phosphorus is unaffected in melting, but there may be a slight increase in sulphur content. This is of the order of 0.005 per cent. The composition of the charge on a furnace with such melting losses will therefore be TC, 3.15; Si, 1.20; Mn, 0.48; S, 0.45 per cent., and P, 0.20 per cent. (max.). In malleable foundries the amount of shop scrap, *i.e.*, the necessary feeders and runners and scrap castings, is in the neighbourhood of 45 per cent. of the metal melted, and this is the controlling feature in the computation of the mixture. The composition of this scrap is that of the hard iron cited previously. Assuming that there is sufficient to make 45 per cent. of the charge the average composition of the raw materials, *i.e.*, pig-iron and steel, must be TC, 3.80; Si, 1.49; Mn, 0.65; S, 0.04, and P, 0.20 per cent. (max.). This necessitates the use of hematite pig-irons. It is convenient for the basis irons to be of two grades as regards Si content, *e.g.*, 1.0 to 1.40 per cent., and 1.40 to 1.80 per cent., the other elements being the same as the average required. It is useful to have other pig-irons for use in small quantities for adjustment of mixtures, with a similar Si content, but with a Mn in one case, low, say 0.25 per cent., and in the other case, high, say 1.25 per cent.

Low grade ferro-silicon, with a Si content of about 10 per cent., is also sometimes charged in small quantities. It might be mentioned here that the chromium content of all raw materials must be low, as it has a very serious effect on graphitisation, as referred to later.

Properties of the Hard Iron.

Fig. 10 shows a micrograph of the hard iron produced. It will be seen that it consists of approximately 75 per cent. pearlite and 25 per cent. free cementite; the dendritic structure is usual for all white irons. A remarkable feature of this low-carbon white iron is its tensile strength, which is about 30 tons per sq. in. It is interesting to record that it is fairly easily machined, and has a Scleroscope number of 45 to 48, equal



(*a*) (*b*) (*c*) (*d*)

FIGS. 8A, B, C, D.—FRACTURES OF TEST PLUGS, ILLUSTRATING PROGRESS OF AIR FURNACE HEAT BEFORE TAPPING.

to a Brinell of 300 to 350. It will withstand considerable rough usage, as it is not nearly so brittle as the ordinary higher-carbon white irons. It has been used with success for castings which would otherwise have to be cast in chilled moulds. This material is regularly being machined to fine limits, and small additions of manganese, in the form of 80 per cent. ferro-manganese, to the ladle when pouring improve its machining qualities, with little change in the analysis.

Melting for White-heart.

The melting of iron for white-heart is usually carried out in the cupola. This is by far the quickest and cheapest melting medium to produce malleable castings. Although this would seem to show considerable saving compared with air furnace practice, the composition of the metal cannot be controlled to such fine limits.

Broadly speaking, any cupola suitable for melting grey iron will be satisfactory for malleable. As the metal required must be low in Si and P, and is always high in S, it will be readily seen that it must be highly superheated to obtain the life necessary successfully to pour the light classes of castings made. It is essential to use good coke, and charge somewhat larger quantities than is usual in cupola practice. The cost of fuel per ton of good castings is very much more than is the case with grey iron, as in addition to the poorer fuel ratio, the percentage of feeders and runners is from two to three times greater.

Apart from the greater fuel consumption, there does not appear to be unanimity on the details of cupola working for malleable. Higher blast pressures are favoured by some, but there is no doubt that this should be governed by the diameter of the cupola and the disposition and area of the tuyeres. The essential requirement is hot, clean iron, and any practice which fulfils this with regularity may be considered good.

(To be continued.)

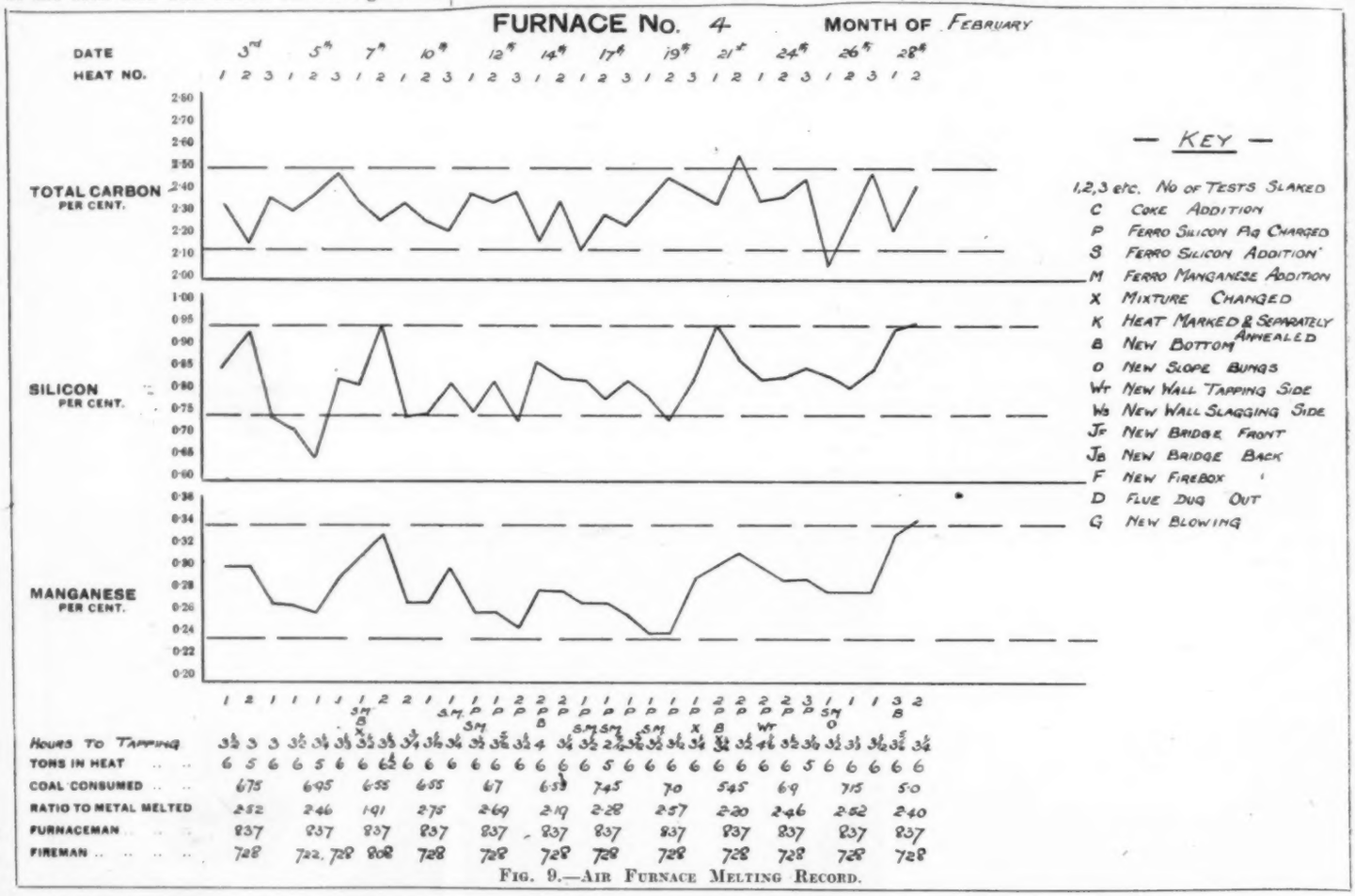


Fig. 9.—Air Furnace Melting Record.

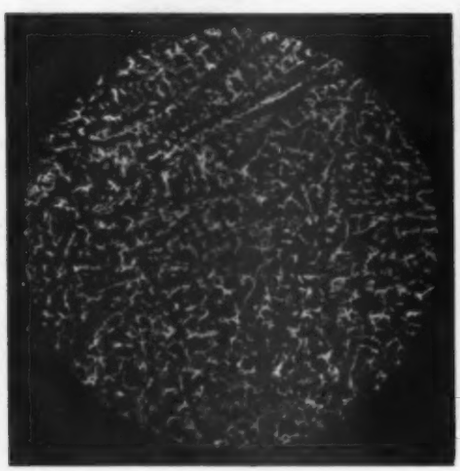


Fig. 10.—Unannealed Black-Heart. Etched × 50.

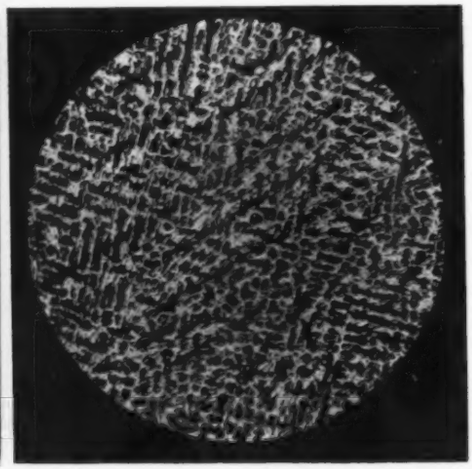


Fig. 11.—Unannealed White-Heart. Etched × 50.

Catalogues Received.

Refractory Materials. To receive from Messrs. Bolckow, Vaughan & Company, Limited, of Middlesbrough, a catalogue dealing with their interests as manufacturers of silica and fireclay refractory products, serves as a very useful purpose, as one is often apt to forget, because of the firm's renown as iron and steel manufacturers, that they have other important activities. A point initially and rightly emphasised is the angular structure of their raw material, ganister, as every one of the 3,000 cupola tenters in Great Britain who handle this material know that the sharper the feel, the better the results obtained from it. The claims initially set out show a real appreciation, and we hope that in the near future they, in common with other manufacturers, will be able to say something about the very important property of heat conduction. We feel that in the light of the present state of knowledge of the subject, silica bricks should not be too highly insulating as it may bestow perhaps more work on the face of the brick than it is capable of withstanding. The brochure contains twenty well-illustrated art pages, and covers descriptions of various grades of silica and firebricks, and ganister and fireclay.

Electric Power in the Foundry—V.

By "KILOWATT."

Electrically-Driven Air-Compressors.

A large amount of work in the foundry is done by pneumatic tools of various kinds, power being supplied by air-compressors. It is not intended to discuss the various designs of air-compressors available, but to confine our remarks to the type of electric motor suitable for driving this plant.

It cannot be said that the problem of driving air-compressors electrically is a difficult one, and provided the right type of motor and control gear is used no trouble should be experienced in its operation. Although the drive from the motor to the machine can be arranged for belt or chain the present-day tendency is to direct-couple the motor to the compressor, the whole being mounted on a combined bedplate. By reason of its high starting torque and reduced starting current consumption the A.C. slip-ring motor is suited for driving air-compressors, and this type can be installed with satisfactory results. There is, however, another type of motor that may be used, i.e., the synchronous motor.

In order to appreciate the characteristics of the synchronous motor it must be remembered that the power factor of the ordinary A.C. induction type motor, working under the most favourable conditions, is well below unity; in other words, by reason of its peculiar characteristics it fails to make full use of the electric current flowing from the mains, utilising only a proportion, say, 75 per cent. The remainder of the current (called idle or wattless current) not usefully employed, is thrown back into the mains, and although the same amount of current that left the power-house is returned, only 75 per cent. has been converted into actual energy, the other 25 per cent. returning unused.

In the eyes of the supply authorities wattless current on their systems is an unmitigated evil, as it means the power station plant running at reduced efficiency, and may well lead to overloading the mains. With the increased use of induction motors supply companies were faced with the necessity of either increasing their plant and cables at a considerable capital outlay, or of insisting upon customers improving the power factor of their installations by reducing, as far as possible, the wattless or idle current of their electrical plant, thus relieving the station plant of unproductive load so that it can give increased useful energy. This is effected by a graduated tariff, by which consumers are usually charged on a definite kw. or power demand with a penalty or bonus if the current falls or rises below or above a certain predetermined power factor. It is, therefore, in the customers' interest to bring the k.v.a. input as nearly equal to kw. output as possible—a factor the importance of which is frequently not realised until the supply authorities begin to charge on a k.v.a. consumption basis.

The Auto-Synchronous Motor.

In order to overcome this problem there has been designed a machine known as the auto-synchronous motor, which is really a special form of induction motor; it starts up against any reasonable load required in a similar manner to the ordinary induction motor, that is, by resistance in the rotor circuit. When the resistance is all cut out, the motor continues to run as an ordinary induction machine, that is to say, it has a small slip, consequently it does not run at exactly synchronous speed. By applying a continuous current to the rotor windings, fixed poles are obtained in the rotor, causing this latter to pull into synchronism with the rotating field in the stator.

While the ordinary synchronous motor cannot be started against any heavy load, and during starting does not develop more than one-third of the full load torque, taking a heavy starting current even to produce that, the auto-synchronous motor possesses the ideal characteristics of good starting and power factor correcting properties.

As indicated above, the low power factor of machines running light affects adversely the total power-factor, so that while the individual power factor of each machine is good at full load, the fluctuations in the load of the whole installation bring the average power factor down to a low value. An auto-synchronous motor, on the contrary, running at light load will tend, according to its design, to give a greater leading wattless component available for advancing the power factor of the total installation, thus a fluctuating load is no disadvantage to an auto-synchronous motor.

With the exception of certain internal modifications, an auto-synchronous motor is essentially the same as an induction type, with the addition of a D.C. exciter belt driven by, or direct-coupled to, the motor. The control gear is precisely the same as for an induction machine, consisting of circuit breaker, with the usual protective devices and interlocked rotor starter. The motor is started up in the usual manner as an induction motor by closing the main switch and gradually cutting out the starting resistance. While running up to speed the exciter builds up the magnetising current, and on approaching full speed the motor pulls up automatically into synchronism.

Overloading.

The question may arise as to what happens to the machine should, during running, an overload occur. Normally, an auto-synchronous motor, which is only arranged to give of itself a power factor of unity instead of a large leading power factor means that the excitation of the rotor circuit is comparatively feeble, consequently, if the machine is subjected to intermittent overloads of a heavy nature it might easily pull out of step. For machines driving reciprocating compressors it is always desirable, therefore, to arrange them to give a leading power factor of 0.9. In actual practice, the leading power factor is usually more than this to correct the lagging current arising from a number of induction motors running on the same circuit.

Should the auto-synchronous motor become heavily over-loaded nothing serious happens, as directly the machine falls out of step it will continue to run as an induction motor. This is a valuable feature under practical working conditions. When out of synchronism the motor recovers immediately the characteristic of an ordinary induction motor, with its heavy overload torque, and when the excessive overload is removed it again pulls automatically into synchronism and resumes its duty of correcting the power factor without any attention.

These machines are suitable for medium and large outputs, for continuous running, where no speed regulation is required, as in the case of pumps, ventilating fans, and compressors.

The New Kryn and Lahy Concern.

The Kryn and Lahy Metal Works, originated in 1915 as a shell shop, which was built on a site at Letchworth a short distance from the present site. The whole of the management, staff and workers were Belgian refugees.

A few months after the small factory commenced operations an extension became necessary. A new site was obtained, and a larger shell shop, which is the present machine shop, was built on it.

Early in 1916, the Board of the Company, realising that there was an increasing demand for steel castings arising out of the munition requirements, decided to take advantage of the fact that many of their workers were specialists in steel casting, and built a factory to cope with this work. No sooner was this in active operation than the tank programme caused an almost instantaneous demand for light steel castings, and the foundry was therefore extended. Towards the end of the war it was producing up to 1,500 tons of light steel castings per month, mostly tank links, etc.

Towards the end of the war, after many million shells had been made and the Company were asked to manufacture aero engine components for Rolls Royce, the shell shop equipment was suitably transformed to cope with these requirements.

At the end of the war the Belgian workers were repatriated, and the Company was faced with the difficulty of reconstituting the foundry plant to enable it to deal with peace time requirements, as against the specialised production of tank links and the like.

During the period of reorganisation the Company carried forward an enormous E.P.D liability, no satisfactory settlement of which was capable of negotiating. This liability effectually prevented any thorough capital reorganisation, and handicapped the undertaking during the succeeding six years by imposing conditions of financial stringency.

Between the end of the war and the summer of 1927 the Company had acquired a reputation as steel founders second to none in this country. It was on the Admiralty, War Office, and all official lists, and was one of the largest contractors in the way of steel castings to the home railways and private locomotive builders.

The reorganised foundry is capable of making steel castings up to 5 tons in weight, and, in some cases, can materially exceed this limit, as witness the strong-room door, exhibited by Messrs. Chubb at the Wembley Exhibition, which was made at the works, and which weighed, door and frame, over 20 tons.

The undertaking has recently been purchased by Messrs. George Cohen, Sons & Company, Limited, and a new company entitled Kryn & Lahy (1928), Limited, has just been formed. The whole of the difficulties under which its predecessors laboured have been removed.

The works, which were fully described and illustrated some two years ago in these columns, are excellently situated as a steel foundry, both from the point of view of raw material requirements and of central situation for despatch.

Certain technical improvements of the familiar Tropenas melting process enable an extraordinary high percentage of scrap and an extraordinary low percentage of hematite to be employed. It is no uncommon thing for 80 per cent. of scrap and 20 per cent. of hematite to be melted.

The locality at Letchworth is extremely favourable for the purchase of scrap on the London market, and this advantage greatly outweighs the cost of the extra haulage south to the comparatively small users of hematite.

As regards foundry coke, Letchworth is nearer to South Wales than the industrial north.

Electricity supplies are remarkably efficient, and very cheap, considering the comparatively small size of the local station.

The First Garden City Company, who own all the freehold in Letchworth, and are the suppliers of gas, water and electricity, have recently assisted by a considerable reduction in the price of electricity supplied to the new undertaking, which will consume a very large proportion of their total manufacture.

Letchworth is well situated for labour supplies, and the housing conditions on the estate are probably the best in England, and the general conditions are conducive to good health and efficient work.

Certain features of the plant deserve particular attention. The mould-drying stoves are fired by the Oehm heating element; Kryn and Lahy were amongst the first few firms in the country to introduce this excellent and economical device, which has effected an economy in heating coke in the ratio of 15 to 2.

Poumay cupola conversion. The two cupolas were converted, one at Easter and one at Whitsun last, to a new and original design, this being the first installation in Great Britain. Many subsequent installations have since followed. It is partly this particular conversion which enables the extraordinary high percentage of scrap to be melted.

Both the sand-handling plant, which is one of the most efficient installations in any foundry in England, and the gravity runways for the handling of material deserve mention.

The formation of the new company has been greeted with enthusiasm by the whole of the old company's customers, and highly satisfactory railway contracts for 1928 have been received.

The entire sales organisation has been recast and strengthened, and, with the general trend of trade on the upward grade, all concerned have the utmost confidence in the success of the new undertaking.

British Facilities for Foundry Training.

No. 1.—THE METALLURGICAL DEPARTMENT OF THE UNIVERSITY OF MANCHESTER.

By Percy Fox Allin, Associate Editor of the "Foundry Trade Journal."

As stated in our previous article, the function of the University is to impart knowledge upon the fundamental science of an industry, and as foundry practice is, in the main, a craft, we shall not, generally speaking, find much apparatus installed in our universities which is directly applicable to foundry practice. The scientific side of the foundry is for the major part metallurgical and it is in that direction that the education of the university student will be conducted.

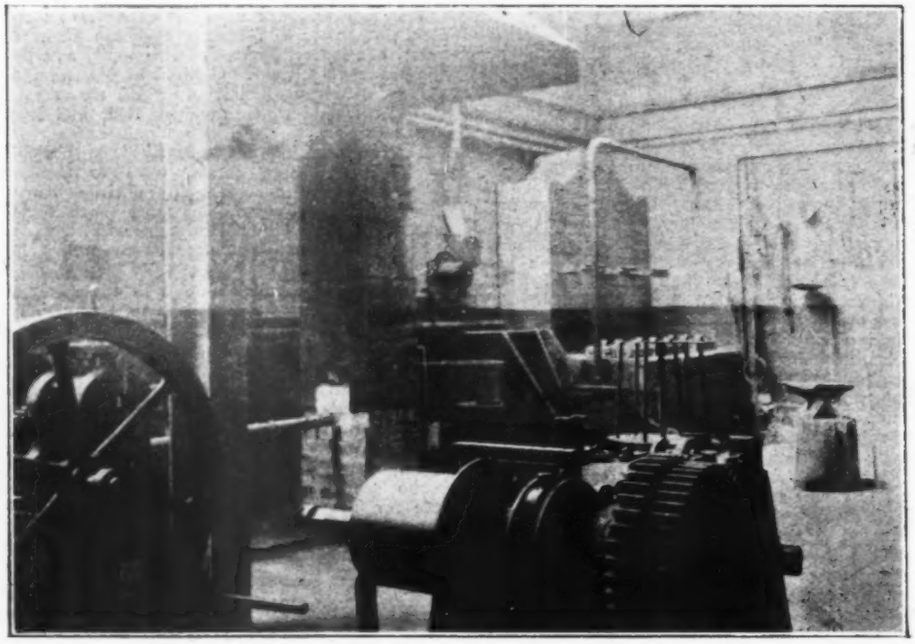


Fig. 1.—Showing Foundry with Wire-Drawing Machine in foreground; Cold Rolls on left. Metallurgical Department of the University of Manchester.

It is well to bear this fact in mind, the technical school may instill the facts and the university the science of an industry, but neither singly nor in combination can they turn out a practical man, for this last a works experience is, of course, essential.

What are the possibilities of the University-trained man for obtaining the necessary practical experience? If he is favourably placed financially he will, no doubt, be able to gain his practical training in the foundry. Unfortunately, however, a considerable number of our most promising students are not men of means, and too often it has been a struggle for their parents to maintain them during their school and university training, and further support is impossible. The only grant available to enable such men to enter the foundry or works is that of the Commissioners of the 1851 Exhibition. That their administration of the fund has been wonderful no one will deny, but the funds at their disposal are wholly inadequate and for the time being there is nothing to supplement them. On the other hand the resources of the Department of Scientific and Industrial Research are ample. The logical result is research is taken up and practical industry loses, it may be, a very valuable man. We do not wish to detract from the value of research, but for the time being we are concerned with the making of a scientifically trained and practical foundryman.

The development of the Metallurgical Department of the University of Manchester dates from 1886, when Professor H. B. Dixon was appointed to the Chair of Chemistry and Metallurgy, it was, however, not until Dr. W. A. Bone was appointed lecturer on Metallurgy and Fuel that the first definite step was taken in the formation of a separate Department. In 1906 the Lectureship was transformed into a Chair, of which Dr. H. C. H. Carpenter, F.R.S., was first occupant. In all these changes Professor Dixon played a most important part, and he it was who collected the money which justified the Council of the University in making the Metallurgical Department independent under its own Professor. No definite endowment was raised, or indeed has this yet been possible.

The Chair of Metallurgy is at present occupied by Professor F. C. Thompson, D.Met.(Sheffield), B.Sc.(London), who succeeded Professor Edwards in 1920. The present laboratories were opened in 1923, actually they are regarded as a more or less temporary arrangement, a much more elaborate scheme was proposed which, when funds are available, it is hoped to carry out.

Equipment Available.

The Metallurgical Department is housed in a block which was formerly used for other purposes. The laboratories include those for chemical analysis, fuel, pyrometry, mechanical testing, heat-treatment, general work, metallography, including photomicrography. There are in addition a small foundry, around which, as a matter of fact, the other departments are grouped, a small machine room, lecture room, and two private rooms for the staff.

The metallurgical laboratories provide facilities for high-temperature work on casting temperatures, heat treatments, etc., determination of the physical properties and mechanical tests of metals and alloys, chemical analyses and fire assays of metals, ores, slags, etc., the microscopic examination and photography of metals, the examination of solid, liquid and gaseous fuels and oils. The electro-metallurgical laboratories which are probably the best equipped in the kingdom, whilst mainly intended for advanced work and research, including especially complete provision for very high-temperature tests, also contain the necessary apparatus for practical instruction in electro-analysis, electro-deposition of metals and the electric furnace and its applications.

Experimental Foundry.

The foundry is equipped with a 3-pot crucible furnace, which is coke fired and used for melting non-ferrous metals, there are also two small injector furnaces, blast being supplied by a Roots' blower. The foundry floor is concreted, a portion adjacent to the crucible furnaces, which is boarded over, can be used for casting when required. In the foundry is also a small pair of cold rolls for manual operation and a small wire drawing machine, also hand operated.

Fig. 2.—Showing General Laboratory. Metallurgical Department of the University of Manchester.

FIG. 3.—SHOWING A VIEW IN THE HEAT-TREATMENT LABORATORY. METALLURGICAL DEPARTMENT OF THE UNIVERSITY OF MANCHESTER.

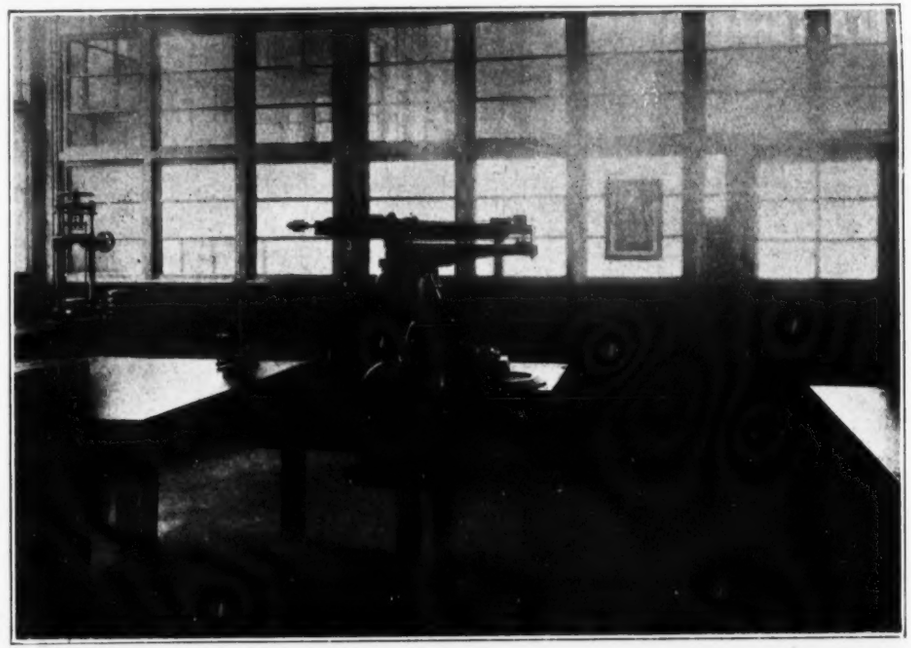


FIG. 4.—SHOWING A VIEW IN THE PHYSICAL TESTING LABORATORY. METALLURGICAL DEPARTMENT OF THE UNIVERSITY OF MANCHESTER.

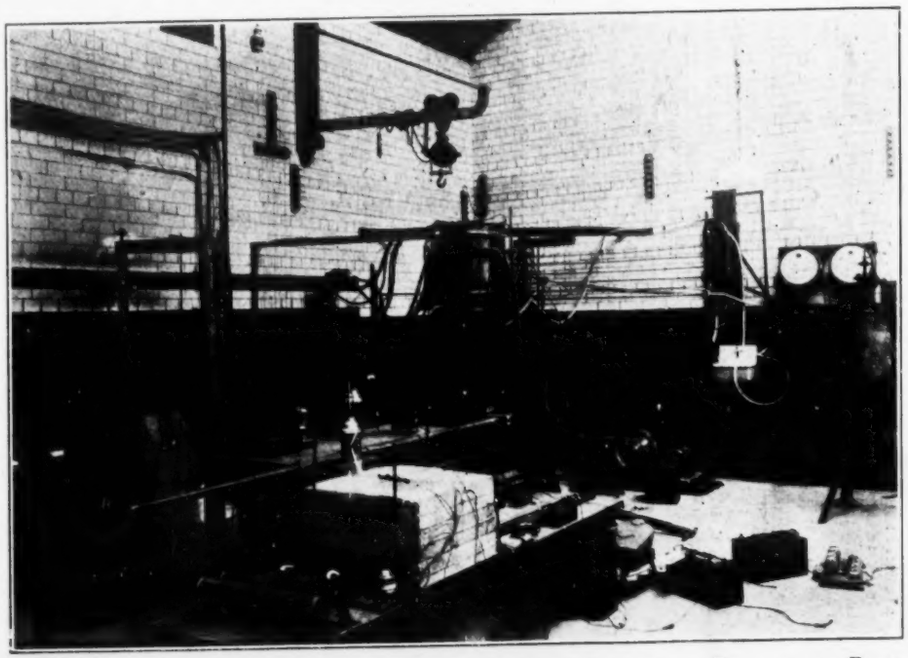


FIG. 5.—SHOWING SPECIAL HIGH-TEMPERATURE FURNACES; APPARATUS FOR RESEARCH ON RADIATION BOXES IN FOREGROUND: NOTE BUSBARS ALONG WALL AT REAR. ELECTRO-METALLURGICAL DEPARTMENT OF THE UNIVERSITY OF MANCHESTER.

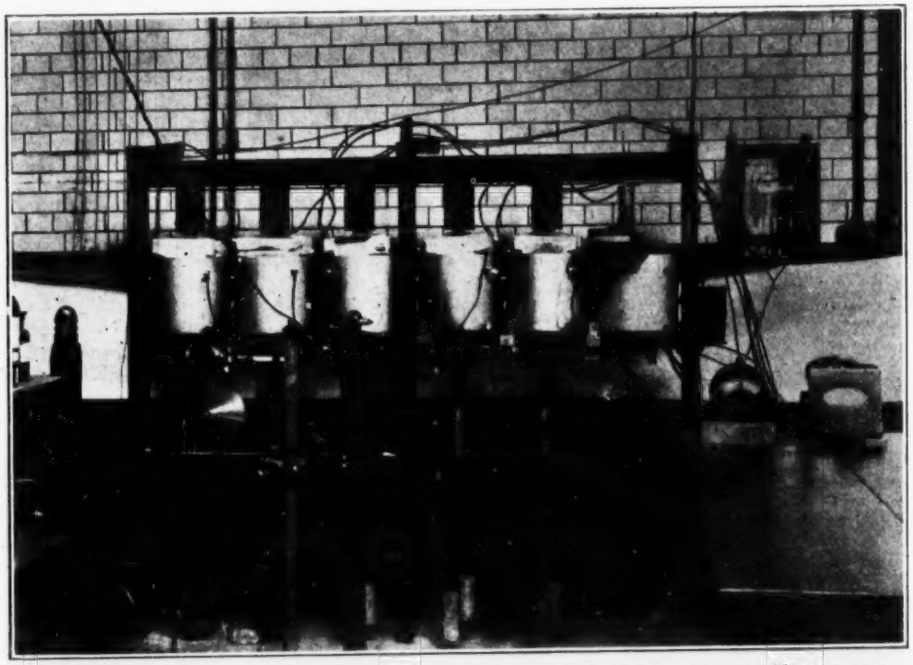


FIG. 6.—SHOWING FURNACES FOR RESEARCH ON THE CREEP-IN WIRE. ELECTRO-METALLURGICAL DEPARTMENT OF THE UNIVERSITY OF MANCHESTER.

In the heat-treatment laboratory, which adjoins the foundry, is a high-temperature furnace, on the surface-combustion principle, by the British Furnaces, Limited, designed for high-temperature work in general and specially for the testing of refractory materials. A muffle furnace, which is heated by a pair of Bunsen burners and in which temperature up to 1,100 deg. C. can be attained, and a Fletcher-Russell double-muffle furnace complete the equipment.

The testing laboratory contains a 6,000-lb. Avery tensile-testing machine, a Stanton alternating stress machine, Brinell sclerscope and Herbert small-ball Brinell hardness apparatus; there are also wire torsion and bending machines.

Electro Metallurgy.

The electro-metallurgical laboratories, as previously stated, are probably the best equipped in the country. Amongst the apparatus installed special mention may be made of the furnaces for carrying out research work at high temperatures and high pressures; a furnace designed for determining the viscosity of molten metal and molten slags, and a furnace designed for the investigation of the influence of gases on the soundness of castings. In this furnace the metal can be melted or boiled under vacuum. There is an apparatus for the investigation and determination of radiation losses from heated surfaces of metals and refractories. Other interesting investigations are being carried out, in a series of six electric furnaces, to determine the behaviour and to measure the creep of wire under load at different temperatures. A high-frequency electric furnace is about to be installed.

In the basement is installed a motor generator set of the Met-Vic manufacture of 40-kw., for converting to A.C. 60 volts, 20 cycles, or D.C. 10/100 volts. The bus bars extend around the furnace section of the laboratory so that A.C. or D.C. can be tapped as desired. In an annexe to the basement is installed a small furnace for use when the charge under treatment gives off harmful gases.

The pyrometry room includes thermo-couples with potentiometers and a modified Wanner optical pyrometer; general apparatus for physical measurements, such as that of low resistance by means of the Kelvin bridge, are housed in the various research rooms. It is intended to add to the equipment in the near future an accurate dilatometer and apparatus for magnetic measurements.

The Future of Alloy Cast Iron.

By "NICK."

A great deal of publicity is being given these days to the development of alloyed cast iron, and some of the more optimistic are telling us that we are witnessing to-day the birth of an era of alloy iron, just as was seen in the case of steel some thirty years ago. Undoubtedly the alloy cast iron has come to stay, and as its properties and manipulation become better understood, so will its field of application become broadened.

Some of the results already published in the case of nickel cast iron are showing properties in common foundry mixtures which until recently were only thought possible in special irons, melted in a special furnace, or heat treated subsequently to casting. Dr. Everest, in his recent Paper given to the Spanish Foundry Congress,* speaks of a cupola iron alloyed with 1 per cent. of nickel, which gave a transverse modulus of rupture of 37.6 tons per sq. in. (on the B.E.S.A. standard "M" bar, giving a maximum stress of 28.4 cwt. and a deflection of 0.33 inch), and a tensile strength of 24 tons per sq. in. But what perhaps is more remarkable about this iron is that whereas thin sections of the motor block castings made from it were grey, nevertheless the heavier sections in the cylinder walls had a Brinell hardness of 215. This is a very high hardness figure for this type of the casting, owing to the fact that it is subjected to very slow cooling conditions through the thermal jacketing of the cores and outer parts of the cylinder block.

But let us not be carried away too swiftly with enthusiasm for this new development, and prematurely proclaim it the salvation of the industry. We have all heard of the beneficial effects of nickel in cast iron, and some of us have experimented with foundry mixtures containing nickel; and the results are sometimes very mediocre, and often the improvement in the castings is so slight as not to justify the cost of nickel added. It is clear, then, that to produce the very best results from the alloy addition, the conditions under which it should be used must be well understood; and as further results come to hand it is becoming more evident every day that the basis of the development of alloy cast iron must lie in the control of the cast iron itself before it leaves the melting furnace.

General Effect of Nickel on Cast Iron.

Reference to any of the literature on the subject will show that nickel has two principal effects on cast iron; it acts as a graphitising agent, but at the same time it hardens and strengthens the pearlitic matrix of an iron. As a result of these effects, we find its principal use in eliminating chill and hard spots in a casting, while it retains or even increases (unlike silicon) the strength of the heavier sections, thus giving maximum overall machinable hardness. This has been amply confirmed by experimental work carried out at Birmingham University under Dr. Hanson. In this lies the usefulness of simple nickel small percentage additions to cast iron.

A study of this claim will reveal to the thoughtful reader the fact that not all cast-iron mixtures are really suitable as a basis for alloyed castings, and in this fact lies the partial disappointment of some of our foundrymen. For example, a mixture may be such as to give a coarse graphitic structure yielding an open, low strength iron. Nickel may strengthen the matrix of the iron, but this benefit is mitigated by the presence of the coarse graphite, over which nickel has little proved definite control, and since the weakness of the casting lies in its graphitic structure, no great net increase in strength results from the alloy addition. Again, an iron may be too soft, its silicon content may be so high that a partially ferritic matrix may result. On such a structure, again, nickel may have little beneficial effect.

On the other hand nickel itself is not readily oxidised; this fact may be the basis of the selection of nickel as an alloy addition, for it means not only that expensive losses do not occur in melting or handling the alloy iron; but, more important, that nickel, unlike aluminium and other easily oxidised elements, is not itself likely to prove the cause of trouble with porosity or dirty inclusions in the metal caused by oxidation or other gas effects. Moreover, it has been shown by many workers that nickel has no deleterious effect on the shrinkage and contraction of cast iron.

Given this information, it is not surprising to find nickel in the forefront in the development of alloy irons. A study of recent work, however, shows up one practical difficulty in the use of simple nickel additions. In a good quality cast iron, as, for example, a motor cylinder iron, a little nickel may beneficially be added to improve overall machinability, by eliminating any tendency to hard spots, and at the same time to give greater hardness in the heavier sections as in the cylinder bores. In this connection it may be pointed out that nickel can have great value in saving hard casts when silicon drops unexpectedly, and gives castings with excess chill. It has been shown, however, that in order to obtain the maximum benefit with nickel, a corresponding drop in the silicon content should be made in order to compensate for the graphitising action of the former, and this introduces the difficulty that a special mix of metal must be made in the cupola to form the basis of the alloy iron. This is a comparatively simple proposition where large tonnages of the alloy iron are required, but clearly is not a practical proposition where only a few alloy castings are called for.

A solution of the difficulty appears to be to hand, in the addition of chromium in suitable proportion with the nickel, and the industry is already hearing good things of nickel-chrome cast iron. Certainly it appears to have a great advantage over the simple nickel iron in that the ratio of chromium to nickel may be so adjusted that no further alteration in the silicon content is required, and the basis of the alloy may be the standard cupola metal run for the ordinary good quality foundry castings. Undoubtedly the trade will hear a great deal more of nickel-chrome in cast iron in the future.

Judging by the recent Paper by Professor Hanson and Dr. Everest,* it is clear that in the more highly phosphoric irons nickel will produce its normal effects, but the general influence of phosphorus is not mitigated by the special alloy additions, and the desirability of the use of low-phosphorus irons for alloyed castings is apparent. This, it is felt, falls in line with the current tendency in the development of high-quality cast iron for engineering purposes.

We have been dealing principally with ordinary foundry cast iron. There seems little doubt that in many of the processes for yielding special cast irons, great improvements may be expected by the judicious use of alloy elements, as has been shown by Piwowarsky.† It is anticipated that in the special irons of the future, probably with low total carbon content, the alloy addition will become an essential part of the composition.

* See FOUNDRY TRADE JOURNAL, Vol. 38, pp. 255 and 274 April 12 and 19, 1928.

* "The Influence of Nickel on Iron-Carbon-Silicon Alloys containing Phosphorus." Iron and Steel Institute, May, 1928.

† FOUNDRY TRADE JOURNAL, 1927, 36, 4 and 37.

Institute of British Foundrymen.

SHEFFIELD SECTION.

Annual Meeting.

At the recent annual meeting of the Sheffield Section of the Institute of British Foundrymen, which was held at the Albany Hotel, Sheffield, the Branch-President, Mr. Ambrose Firth, was in the chair, and before the business was begun he referred to the tragically sudden death of Lieut-Commander L. Jackson, R.N. He said that only a week ago that night Commander Jackson was with them at their meeting, and it was very sad indeed to know that he had been called away so suddenly. He had been a very regular attender and a very active man. He was always a very great supporter of the Institute. He asked all members to stand for a brief period in respect to his memory. This was done. The President announced that members of the Institute would attend the funeral.

The following officers were elected:—President, Mr. J. T. Goodwin; Senior Vice-President, Mr. G. Oxley, Junior; Junior Vice-President, the Hon. J. M. W. North; Secretary, Mr. T. R. Walker; Treasurer, Mr. T. R. Walker. The following were elected as new members to the Council:— Messrs. G. E. Roberts, E. J. Brown, and W. T. Kitching; Auditors, Messrs. G. C. Castle and A. Whiteley; Delegates to the General Council, Messrs. R. H. Hyde, C. W. Hampton, and G. L. Oxley.

Tribute was paid to the excellent work Mr. Walker had done for the Branch, and to the long and valuable service Mr. Macdonald had done both as secretary and treasurer.

MR. HYDE said their President, Mr. Firth, had, during the past year, done very well indeed for them. Those who had done the work knew that it was not all done in that room. Mr. Firth had carried on the work to their utmost satisfaction, and, he hoped, to the pleasure and advantage of himself.

MR. FIRTH said that what he had done he had only been too pleased to do. He should not relinquish his interest in the Branch and in the Institute as a whole, but should always do what he could for them.

Mr. J. Shaw, a Past-President of the Sheffield Branch, a recognised authority on foundry matters, whose views on subjects connected therewith are respected by a great majority of foundrymen not only in this country but in others, then gave a Paper on "Theory or Practice in the Grey Iron Foundry," which he also presented to the American Foundrymen's Association, and appears in this issue of the JOURNAL.

Aluminium Casting Alloys.*

A REVIEW OF RECENT PROGRESS.

By George Mortimer, M.Inst.Brit.F.

Anyone asked to submit a Paper on progress in the casting alloys of aluminium must almost inevitably find himself tending to sit down between two stools. On the one hand, is an almost limitless mass of technical data, patents specifications, trade advertisements. On the other, the fact that a visit to the despatch department of most of the large jobbing foundries would show little apparent advance to the superficial observer, would indicate, in fact, that the bulk of work going through was being cast in alloys familiar to aluminium founders for the past twenty years.

Engineers as a class tend rightly to conservatism in choice of materials, however embarrassingly progressive they may sometimes be, from the founder's view-point, in the matter of design. The British Engineering Standards Specifications for light casting alloys cater well for average requirements, and the founder is content to supply them to the best of his ability as long as the demand is maintained.

The years since the war, however, have been marked by two definite developments of interest to founders of aluminium. In the first place the demand made on cast light alloys has undergone a complete change, following fundamental changes of ideas in regard to transport. Automobile and aircraft designers lean continually towards higher performances for a given weight, bringing more severe stress and temperature conditions than formerly.

An Ever-widening Field.

The rapid expansion in road transport has in itself introduced new problems in regard to maximum seating or freight capacity for a given axle-loading, and the same line of thought is influencing our railways. The marine engineer has entered the field with his demand for alloys resistant to corrosion. Aluminium castings are finding their way into all sorts of unsuspected byways of industry, each with its own peculiar problems to be solved by the metallurgist or the founder, or preferably by both.

The second development is a natural corollary of the first in that demand creates supply. Industrial demand for alloys of special properties has resulted in an overwhelming array of new specifications, and in an immense expenditure of printers' ink, so that the average busy man finds it difficult to see the forest for the trees. In addition to the B.E.S.A. alloys there are many proprietary alloys employed in this country, whilst in America there are at least fifteen or sixteen different alloys of zinc, copper, nickel, tin, manganese, magnesium, silicon, etc., in all sorts of combinations, in current use. In what direction or directions lies the progress?

The reply to that is rather easier than it looks because of one quite simple point. The range of physical properties obtainable by alloying aluminium with other metals appears to have quite well defined limits. All the above alloys when cast in standard chill moulds would give tensile strengths within the range of from about 9 to 13 tons per sq. in., with from 2 to 6 per cent. elongation. It is possible that if the whole list were melted down together these properties would not greatly alter, and it is certain that the existence of fully fifty per cent. of them is unjustified by any property of peculiar value either to the engineer or the founder.

The real progress of the past ten years lies not so much in the discovery of new alloys, as in methods of dealing with them after they are alloyed. Aluminium-silicon alloys pre-dated pure aluminium, but it is only during the past few years that the process of "modification" has been deliberately applied to them on a commercial scale, with effects on their physical properties of far-reaching importance. The very first "aluminium" produced commercially in this country was an aluminium-copper alloy, but many years were to elapse before the mechanism of heat-treatment was studied and applied to this simple group, resulting in a material like duralumin. Practically all real progress of interest to founders, therefore, can conveniently be considered under very few headings, as follows:—(a) Purification of melts; (b) heat-treatment; (c) modification; and (d) protection.

Purification.

One of the most illuminating pieces of work on this subject, and the one of most immediate use to founders, was the Paper read by Mr. S. L. Archbutt in 1925. All aluminium founders have experienced that insidious trouble known colloquially as "speckled metal," a pinholed appearance that shows up at a machined surface and spoils an otherwise good casting. (See Figs. 1 and 2.) The difficulty in regard to this type of defect is its erratic appearance and disappearance in phases throughout a foundry. Whatever care may be taken in purchase or melting of materials, whole batches of castings can be affected one week, whilst castings may be produced for several ensuing weeks without the defect, and without any apparent change whatever in methods or stocks of metal used.

In ordinary commercial work this defect has been regarded as unsightly rather than serious, but with the growing necessity of the aircraft industry for castings as solid and sound as metallurgy could make them, this long-known trouble began to assume a greater significance.

Archbutt showed that the difficulty was due, not so much to dirt or dross or complex inclusions,† but to dissolved gases, mainly hydrogen. Aluminium tends to absorb gases into solution with a readiness diminishing in the following order:—Hydrogen, coal gas, carbonic acid, sulphurous acid, oxygen, air, carbon monoxide, nitrogen, the last-named being for all practical purposes insoluble. Gas tends to come out of solution when the metal is allowed to solidify slowly. Thus, if a heavy section of a casting is heavily chilled a fine machined surface is obtained. If instead it is fed with a large riser, it solidifies more slowly, and gas comes out of solution only in time to be caught and held in the solidifying metal. Hence the porous appearance. Carrying the idea a little further, if cooling were so slow that gases not only came out of solution but also had time to leave the melt, then the metal might be freed of much of its gas content.

The essence of the Archbutt method, therefore, lies in allowing the metal to solidify in the melting pot, and immediately on solidification to bring it up to the pouring temperature again. A refinement consists in assisting the released gases free of the melt by passing a stream of nitrogen through during the cooling process. The effect of this can be seen at once by the intermittent burning of a typical hydrogen flame at the surface for several minutes after turning on the nitrogen.

This discovery, for it amounts to no less, has been of genuine service as affording a logical explanation of a difficult and illogical phenomenon. In the author's experience neither the pre-solidification nor the passage of nitrogen through a melt offer any practical obstacle in foundry routine. The special castings for which such refinements are needed command a special price, and the chief consideration is whether that price is justified in practice by consistency of results. In practice the method certainly results in sounder work in the case of "Y" alloy and the modified silicon alloys, of which more hereafter. In the case of the copper and the copper-zinc series results are more erratic.

It is of interest to note that concurrently with Archbutt's work at Teddington, similar research for the British Non-Ferrous Metals Research Association was producing similar results in regard to copper, in the hands of Mr. Prytherch, at Swansea. In the light of these researches and subsequent practical experience on a routine foundry scale, it would seem that much of the trouble assigned to ingot aluminium may, in fact, be due to the alloying medium. Sections in a good grade of commercial aluminium may be cast in sand, and show, on machining, no trace of pinholes. Some of the same ingot may be alloyed with copper and at once show the typical pinholed appearance. It seems that other metals may introduce a detrimental amount of hydrogen or other gas into a melt, or alternatively act in some manner as a releasing agency for gases already in solution.

The Archbutt Method.

Be that as it may, in applying the Archbutt method the author finds that from the practical standpoint quite as good results may be obtained in the case of copper alloys by treatment of the 50-50 hardener only. It is further suggested that omission of the nitrogen treatment results in no very apparent difference in results, and in practice may be an advantage because of the ever-present possibility of continuing the stream of gas too long in a solidifying melt; entangled nitrogen can cause just as much porosity as precipitated hydrogen. The reduction of the process to a simple one of pre-solidification of the relatively small 50-50 melt brings it more nearly into the realm of practical politics. The treatment of a 1,500-lb. melt of the final alloy is far more costly, since in the author's experience it may take two hours or over to solidify in the pot.

Erratic results from this pre-solidification process may be due, not to failure of the method as such, but to extraneous factors. It is possible to remove all gas of practical detriment, and to contaminate again on re-melting owing to exposure to furnace gases. It is possible to remove hydrogen, and yet to obtain in the end a pinholed machined surface through entrained air, brought in by undue stirring of the melt, splashing during ladling, turbulence in entering the mould. It is quite possible to pour out a sheet of academically-clarified metal on to a flat sand surface, and to get speckled castings every time through gases released from the sand and caught in the solidifying metal. All these pitfalls cannot always be avoided, but to get the most consistent results from the Archbutt method the writer recommends certain precautions.

Desirable Precautions.

(1) Plumbago crucibles at high temperature appear to offer little resistance to the passage of furnace gases. Use an iron, Perlit, or Nichrome pot, thoroughly dressed with an aqueous solution of graphite, whiting and water-glass.

(2) Avoid all stirring or disturbance of the melt until just before pouring. Then skim, and stir well from the bottom upwards, disturbing the surface as little as possible. Skim again thoroughly and pour without delay.

(3) Wherever practicable, arrange for transport of the actual melting pot to the mould, and so avoid the great disturbance of ladling or tilting into crucibles.

(4) Arrange for gates which lead the metal down into the mould as smoothly as possible, without right-angle bends or sudden drops.

The above precautions suggest the realm of fine art rather than the atmosphere of the jobbing foundry. High-class aluminium founding, however, has always been an art rather than an exact science. It is doubtful whether it can ever be the latter, but Archbutt's contribution to knowledge is one definite step in that direction; a step which has brought about a standard in light-alloy founding regarded, only two or three years ago, as a frank impossibility.

It is to be observed, however, that such standards are at present only maintained at a relatively high cost, and, secondly, that in spite of the useful lead given by science, we are as yet only on the fringe of a very intriguing subject. If hydrogen alone accounted for pinholes in castings this elusive gas would present sufficient problems for the average working founder, but the evidence goes to indicate that hydrogen is not the only gas involved, and that no gas or combination of gases accounts for all "speckled metal."

* A Paper read at the Leicester Convention of the Institute of British Foundrymen.

† "Journal Institute of Metals." 1925. No. 1.

Messrs. D. and J. Tullis indicate a useful line of research in patents Nos. 28388/25 and 11221/25, wherein it is claimed that chlorine or its compounds passed through the melt combine with carbon, iron, hydrogen, nitrogen and other deleterious elements. These impurities are brought to the surface as gases, carbide or oxides, resulting in a refined grain and relative freedom from gas cavities in the casting. (See Figs. 1 and 2.)

The growing knowledge of the profound effect of gases on the properties of metals and alloys, and the fact that many enter readily into solution with metals, points to a future when we may not be so anxious to rid our metals of gases, concentrating rather on the introduction of some particular gas which will endow the material with valuable physical properties.

Heat-Treatment.

The heat-treatment of aluminium-alloy castings is intimately bound up with the question of initial soundness. The principle or mechanism of heat-treatment is the same for all the hard alloys of aluminium, and probably the simplest illustration is that of the straight 4.5 per cent. copper alloy described by Hanson and Gaylor* in 1923.

Reference to the constitutional diagram of the aluminium-copper system shows that copper will go into solid solution in aluminium up to about 5.5 per cent. at 548 deg. C., but that only 1 to 2 per cent. are normally retained in solution at room temperature.

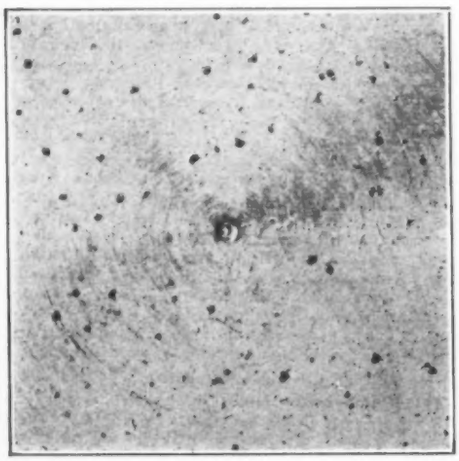


FIG. 1.—SELECTED EXAMPLE OF PINHOLING IN 3L11 ALLOY. SAND CAST IN HEAVY SECTION.

If, therefore, an alloy be made up containing between 4 and 5 per cent. of copper, its microstructure will resemble that shown in Fig. 3, and will consist of primary crystals of aluminium containing about 1.5 per cent. of copper in solution, and surrounded by a network of the hard eutectic compound $CuAl_2$. If the alloy is now maintained for some hours at a temperature of 540 deg. C. much of the $CuAl_2$ network is absorbed gradually into solution in the primary crystals, as seen in Fig. 4. Abrupt quenching at this juncture fixes the excess copper in solution.

The material is now in an unstable condition; it contains more copper than is normal at room temperatures, and the tendency is for that copper to re-precipitate slowly in an extremely finely-divided form. No deformation of a metal can take place without relative movement between the planes of easy slip of the matrix, and the theory propounded by Merica is simply that the presence of fine particles of a hard precipitate causes such relative movement to absorb more work, like grit in a bearing. Therefore deformation of the metal is more difficult. It is "harder."

In practice precipitation is hastened by a low-temperature annealing operation, at temperatures varying from 100 to 200 deg. C. The effect of this series of operations, a "solution treatment," followed by quenching and a "precipitation treatment" may be seen in Table I:—

TABLE I.—*Mechanical Properties of 4.5 per cent. Cu Alloy.*

Condition.	M.S., tons per sq. in.	E. per cent. on 2 ins.
Chill cast	10 to 11	10 to 14
Heat-treated for 24 hrs. at 500 deg. C., quenched, and held in boiling water 1 hr.	16 to 17	18 to 25

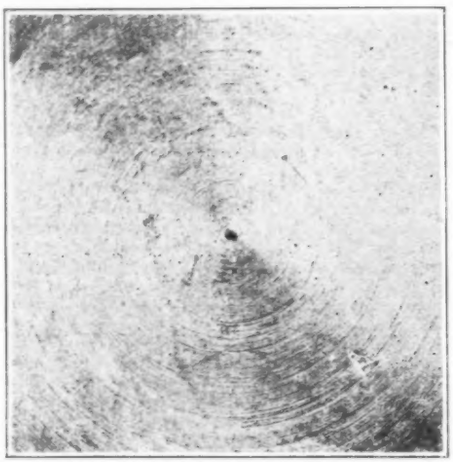


FIG. 2.—SPECIMEN FROM THE SAME MELT AS FIG. 1. TREATED WITH CHLORINE GAS BEFORE CASTING INTO THE SAME MOULD.

From the metallurgical standpoint this result is sufficiently interesting, being obtained by a simple thermal process as distinct from hot or cold working. Obviously the field for castings is theoretically broadened at once.

It will not escape the notice of the initiated, however, that the above results are obtained on specimens seldom encountered in routine commercial work. Test bars of even section, cast in chill moulds under most carefully controlled temperature conditions, offer a strong contrast to a sand casting of average intricacy. The one, by reason of its inherently higher physical properties, its soundness and refined grain, offers an easy medium for the inter-diffusion of the solid components of the alloy. The other starts with a handicap of lower physical properties, and it is seldom that the section of the casting, the temperature or the speed of pouring, can be chosen for the best metallurgical results. In the case of the chill-cast bar there can be almost perfect feeding throughout: this also is possible in many sand castings, but the mere presence of a large riser to feed a heavy section brings about a slow local solidification. Slow solidification results in the formation of larger crystals than are ever found in a chill-cast bar, and in discontinuities between those crystals; it may result also in the liberation of gases in the form of pinholes; and none of these conditions conduce to that ready absorption of constituents into solid solution so essential to results.

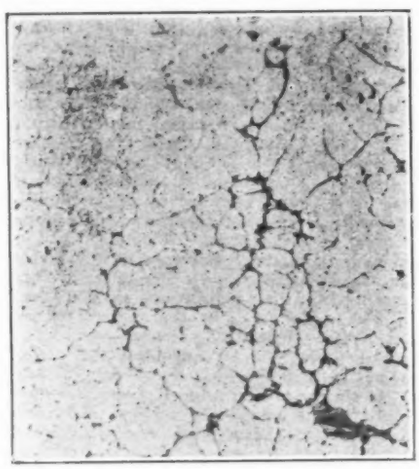


FIG. 3.—4.50 PER CENT. COPPER, 0.32 PER CENT. SILICON, 0.22 PER CENT. IRON. SAND CAST. ETCH $Fe(NO_3)_3$. × 60.

The net result is primarily that heat-treated sand castings do not give the results obtained on an ideal, chill-cast bar. Secondly, sand castings as a rule call for longer periods of soaking than are required either for chill castings or forgings. There is an alternative in that higher temperatures may be used for shorter periods, but in practice this brings in new difficulties in regard to supporting castings against distortion in the furnace, or against partial collapse in removing to the quenching bath.

The striking possibilities opened up by heat-treatment of the simple copper alloys, however, stimulated the exploration of other compounds which, like $CuAl_2$, decreased in solid solubility with fall in temperature. For example, magnesium itself when added in small quantities to aluminium has little tendency to go into solid solution and reprecipitate. It forms with the silicon impurity always present in aluminium, however, a compound Mg_2Si which behaves much in the same manner as $CuAl_2$. An alloy containing 1.16 per cent. magnesium and 1.02 per cent. silicon gives as sand-cast a tensile strength of about 8.5 tons per sq. in. with 3 per cent. elongation. When soaked for 96 hrs. at 552 deg. C., quenched in cold water and held at 150 deg. C. for 8 hrs., the bars will give 15 tons per sq. in. with 6 per cent. elongation.

FIG. 4.—4.50 PER CENT. COPPER, 0.32 PER CENT. SILICON, 0.22 PER CENT. IRON. SAME ALLOY AS FIG. 3, BUT HEATED FOR 12 HOURS AT 525 DEG., AND QUENCHED IN COLD WATER. ETCH $Fe(NO_3)_3$. × 60.

Combining $CuAl_2$ and Mg_2Si in the one alloy produces duralumin, an alloy which can be hardened by heat-treatment in the cast condition just as in the wrought. With 4 per cent. Cu, 0.2 per cent. Mg, and with the iron content kept down to 0.25 per cent., up to 22 tons per sq. in. with 8 to 9 per cent. elongation has been obtained on heat-treated sand castings. The addition of a very small percentage of manganese to this class of alloy, copper plus magnesium silicide, does no harm and tends to refine the grain.

In the 4 per cent. copper alloy and its variations it appears desirable to keep the iron content as low as possible: the presence of iron tends to check precipitation, at any rate as far as castings are concerned. The iron content may be made less harmful, however, by the deliberate addition of silicon, forming either an iron silicide or a ternary compound which causes less trouble.

(*Continued on page* 437.)

* "Journal Institute of Metals." 1923. No. 1.

Theory or Practice in Grey-Iron Foundry.*

By John Shaw, Southsea.

PART I.

Certain inspired references to the ignorance and want of initiative in research on the part of the practical iron founder has led the author to present for plain discussion, points that have some bearing on the question. To quote from one of the mildest of these critics, "much border line work could be captured from steel by the commoner material if the iron founder would follow the example set by the progressive steel founder," again, "to succeed led inevitably to the laborious synthetic method," etc. Now is this indictment a true one, and, if so, why?

In the first place a mild-steel casting is a very simple metallurgical problem (we are not referring to moulding and other difficulties), and consists of only two elements that matter, iron and carbon, the others being either "cleansers" or in the case of sulphur and phosphorus "kept as low as possible." Under these conditions one can understand the utility of the binary or ternary diagrams, especially in view of the after heat treatment. Complex cast iron, on the other hand, is influenced by all six elements, each having considerable bearing on the final product. The history of steel also reveals the fact that it was not possible to make sound steel until the accidental discovery of the deoxidising effect of manganese. Unfortunately, in some respects, fairly good cast iron can be obtained by simply mixing pig and scrap in any corner cupola, hence the lack of apparent need for research, combined with the fact that the price paid has left no margin.

A glance at the analyses of a typical mild-steel casting, and a cylinder iron (Table I) shows that their only similarity consists in that both contain the same elements, but in totally different proportions.

TABLE I.—*Comparative Analysis of a Typical Mild Steel Casting and a Cylinder Iron.*

	Per cent. T.C.	Per cent. Si	Per cent. Mn	Per cent. S	Per cent. P
Steel Specification ..	0.2 to 0.4	0.26	0.6	0.04	0.04
Cylinder Iron ..	3.0	1.2	0.8	0.12	0.3 to 0.8

In view of the above analyses, has not the attempt to apply to cast iron the theories evolved in the case of steel been a hindrance to progress, rather than a help? The statement that cast iron is simply a steel interspersed with graphite may be useful to the teaching profession, but there is no doubt it has not helped to a better understanding of complex cast iron. In short, is the synthetic method of approach that was successful in steel, the best for cast iron?

Many research workers have tackled cast iron by choosing some particularly pure white iron, with the result that much literature exists concerning metal of such qualities and compositions as are met with in no foundry in the world.

To take only one instance, it is nearly 20 years since Gonterman published his work on the effect of silicon. Last year there appeared a most carefully prepared Paper by Dr. Hanson on the same subject, putting forward a new theory that might reconcile the divergent views as to the primary graphitising point. At the same time, valuable as this contribution was, especially on the scientific side, it has added little to our knowledge of the ultimate structure that was not previously known. As the author states, the other elements in cast iron may alter the results, and also in cooling, equilibrium may seldom be reached. All the recent advance in cast iron has been founded on a cast-iron base, having all the elements present in such quantities as are found in cupola work of which the work by Lanz, Emmel, and Donaldson are examples.

If we take the elements in rotation as found in the two previous analyses, we find the total carbon of the steel casting limited to 0.2 per cent. to 0.4 per cent. Up to this limit, according to Charpy, no graphite is formed at any temperature in the presence of even 2 per cent. silicon. In cast iron the carbon may be anything from 2.5 per cent. to 3.5 per cent., and every element, melting temperature and mould temperature has an effect on the final product. Even if the composition gives a pearlitic structure, the tensile strength may vary from 9 tons to 17 tons, due entirely to the form and quantity of the graphite and variation in the type of pearlite.

Effect of Silicon.

The silicon in mild-steel castings is about 0.2 per cent. Its function is to act as a cleanser and give rather better running qualities. In cast iron, silicon is one of the dominating elements, and its influence on the condition of the carbon has much to do with the physical properties of the resultant casting.

It is 40 years since Professor Turner's famous investigation on the effect of silicon on cast iron was completed. Turner states that the interest taken in cast iron at that time and during the next few years was truly remarkable, and was not confined to any single country. Without in any way diminishing the value of this discovery, there is no doubt that the abuse of the use of silicon has done not a little to lower the physical properties of cast iron. A quotation from Keep's Paper before the Philadelphian Foundrymen will exemplify this: "Silicon is the only thing necessary to the foundry, all other things in cast iron can be overlooked. If the shrinkage is not low enough—if the iron is too hard or not grey enough, add silicon, it remedies all other defects. It is the only variable to consider, and it is the easiest to manage." While this quotation is extreme, there is no doubt that in the craze for fast machining on one hand, and the softening of cheap materials, irrespective of their composition, silicon additions are still used to the detriment of the physical properties.

With the advent of the Institute of British Foundrymen, fresh interest was created in the various problems. The personal interest of Professor Turner in this movement led to the remarkable series of investigations undertaken at Birmingham University. Those of Levi, Coe, and Hague are quoted to-day. Hatfield, who at that time was interested in malleable, also did some good work. Hague presented a Paper before the Iron and Steel Institute on the influence of silicon on pure cast iron in October, 1910, while Coe, following other Papers, dealt with the physical properties in 1913. Broadly speaking, the results agree, that is, with the separation of graphite, due to the effect of silicon, the strength and hardness of the bars decrease.

One of the points that seems to have been overlooked was the effect of comparatively wide variations in carbon. The chief object in using a synthetic mixture was to be sure that there should only be one variable, yet in all these experiments the carbon varied between 2.26 per cent. and 2.95 per cent., a difference of 0.69 per cent. This would make a considerable difference on the final structure and strength of the unannealed bars.

An examination of any published chart of blackheart malleable giving depth of chill in relation to carbon and silicon content, shows that with silicon below 0.7 per cent., two parts of carbon will have the same effect as one part of silicon on the depth of chill. With the silicon from 0.7 per cent. to 1.2 per cent., four parts of carbon are equal in effect to three parts of silicon. As the chill disappears at the higher silicon this is as far as definite knowledge goes; it is also known quite definitely that the addition of 0.06 per cent. silicon to an analysis just mentioned will decrease the depth of the chill ¼ inch, so roughly the effect of carbon on the structure can be calculated.

Since the war the formation of the British Cast Iron Research Association has led to fresh interest in cast iron problems, of which the paper mentioned, by Dr. Hanson, is one result. The author has purposely not gone into details concerning the various investigations, because of the ground desired to be covered, but anyone interested will find the whole question dealt with, either in Turner's, Hatfield's, or Hurst's books. Table II gives roughly the results of the various workers, the size of the bars and method of casting varied so that the results are not very helpful, although the influence of silicon is shown.

TABLE II.—*Bar Sizes used in Representative Researches.*

	Hatfield.	Hamasumi. 1st Series.	Hamasumi. 2nd Series.	Hague.	Coe.
Per cent. total carbon ..	3.07 to 2.95	3.35 to 3.33	2.90 to 2.93	2.47 to 2.95	2.88 3.04 3.22
Per cent. combined carbon ..	0.06 to 2.03	0.66 to 0.90	0.63 to 1.13	0.97 to 2.82	1.08 1.27 3.19
Per cent. silicon	1.72 to 1.68	2.90 to 1.18	2.90 to 0.64	1.95 to 0.66	2.03 0.80 0. 4
Tensile strength, tons ..	12.07 to 11.41	7.44 to 10.07	16.05 to 18.04	—	13.72 10.06 14.33
Size of bar	1″ × ¾″	1¼″ round	—	1″ square	1″ square.

The data of Table II raises the whole question of the suitability of using small bars to obtain results on which are based such diagrams as Maurer's. A 1-in. square or 1¼-in. diameter bar presents so much superficial surface in relation to its cubical content that the quick cooling rate masks large variation in composition, of which the data of Table III taken from the figures in the latest Maurer diagram are samples, yet these showed all-pearlitic structures.

Manganese.

This element in mild steel castings is useful as a deoxidiser, to neutralise the effect of sulphur, and also to increase the yield point and ductility. In grey iron investigations have been made by Stead, Coe, Wüst and others. The position at present is best summed up by Hamasumi; first, that manganese up to 2 per cent. in the presence of silicon as in grey iron, does not retain carbon in the combined form; and, second, that with the increase of manganese the pearlitic structure is considerably altered and tends to be sorbitic. Hence the increased Brinell hardness with no increase of combined carbon; with more than 0.5 per cent. the tendency is for the graphite to be in "whirl" form. Manganese also improves fluidity and tends to a sound casting.

TABLE III.—*Analyses both showing all Pearlitic Structures.*

T.C.	C.C.	G.C.	Si	Mn	P	S	Total and Silicon.	Brinell.
Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
2.07	0.91	1.79	1.36	0.77	0.50	0.09	4.06	161
3.81	0.87	2.94	1.44	1.23	0.06	0.06	5.25	106

There is so large an amount of evidence on the first point that one wonders at the often repeated statement, that manganese after satisfying any

* A Paper presented to the Philadelphia Meeting of the American Foundrymen's Association and to the Sheffield Branch of the Institute of British Foundrymen. The author is the well-known British foundry consultant.

sulphur present, hardens cast iron in the proportions usually found. Outerbridge stated that this is a mistaken notion and gives proof. A glance at Coe's or Hamasumi's tables also confirm this. Dr. Howe, discussing Hatfield's paper, states "The influence of manganese in increasing the stability of the carbide is opposed by some additional fact, as has so often been noticed. For instance, Dr. Hatfield's S33 and S23 are closely comparable except manganese, and so are S34 and S24. After heating to 950 deg. C., the higher manganese specimens in both cases graphitise more than the lower manganese ones."

Wüst and Miny in their paper on sulphur in cast iron say, "Sulphur counteracts the graphitising effect of manganese."

Table IV.—*Influence of Manganese on the Properties of Pure Cast Iron.*

Authority.	T.C.	C.C.	Si	Mn	S	P	Lbs. Transverse strength bar 12″ ×1″×1″	Deflection in inches.	Tensile strength tons per sq. in.
Coe	3.28	1.13	1.00	0.014	Tr.	0.09	2,732	0.094	12.67
Coe	3.15	0.82	1.02	0.846	Tr.	0.09	3,461	0.092	16.59
Coe	3.02	0.92	1.62	0.04	0.015	0.093	2,665	0.132	10.10
Coe	3.04	0.43	1.50	1.03	0.015	0.093	3,035	0.11	15.11
Coe	2.79	1.06	2.24	0.016	0.016	0.027	2,240	0.08	9.92
Coe	3.03	0.69	2.42	1.96	0.016	0.027	3,203	0.12	15.47
Hague and Turner	2.77	0.84	3.06	Tr.	Tr.	Tr.	—	—	—
Hague and Turner	2.62	0.22	3.00	0.50	Tr.	Tr.	—	—	—
Hamasumi	2.90	0.82	1.65	0.15	0.02	0.01	—	—	16.8
Hamasumi	2.89	0.76	1.72	0.30	0.02	0.01	—	—	18.7
Hamasumi	2.96	0.86	1.61	0.69	0.02	0.01	—	—	19.9
Hamasumi	3.04	1.07	1.71	1.34	0.02	0.01	—	—	22.3
Hamasumi	2.84	0.77	1.85	3.94	0.02	0.01	—	—	26.3

Table V.—*Author's Chill Tests as Effected by Manganese-Sulphur Ratio.*

T.C.	C.C.	Si	Mn	S	P	Depth of Chill on Test Piece	Depth of Chill on Roll.	Loss.	Mn to S Ratio.
2.96	0.55	0.05	0.42	0.089	0.45	2¼″	¾″	1½″	4 to 1
3.16	1.37	0.83	0.27	0.164	0.05	1½″	½″	1″	1.5 to 1

Coe in a later paper on the influence of metalloids on properties of cast iron, replying to the discussion, states "The experiment performed by Hague on the influence of 0.5 per cent. manganese has been repeated under the same conditions, and also under very different conditions, always with the same results; so that it may be definitely stated that in siliceous cast irons with the ordinary rate of cooling, the addition of the first 0.5 per cent. manganese results in a softening, owing to the precipitation of secondary graphite."

Allison, in a paper on chilled rolls, states "Ferro-manganese was added in the ladle in several instances, but it was found that thereby the amount of chill is seriously affected. What appears to be a critical point is a percentage of 0.36 per cent. manganese, and it was found undesirable to have the manganese content any higher." Table IV gives the results of the various workers, with a minimum of sulphur present. Whether this graphitising action of manganese is a direct one or, whether it is simply due to the considerable lowering of the pearlite point, is left to abler metallurgists. The latter, combined with the shorter freezing range, would account for the finer graphite usually found and also for the higher Brinell number without affecting the machining speed. The latter theory would also offer an explanation for the necessary time element noticed with the graphitising effect of manganese. For instance, Cook found if he raised the manganese above 0.4 per cent. the castings were liable to machining trouble in the bore of the cylinders. As the main body core was chilled-lined, the cooling rate would be too quick to allow the secondary action of the manganese.

Personal experience (Table V), with certain rolls, points the same way. This is attributed to the excess ratio of manganese to sulphur.

The chill test in the first shows 2¼ in., while the roll only shows ¾ in., a loss between the chill test and the roll of 1½ in. The second roll only showed a variation of ½ in.

Loudenbeck in a paper before the American Foundrymen's Association gave a number of instances: "In the manufacture of large hydraulic cylinders it is necessary to have a close mottled structure to withstand breakage and prevent leakage. If the manganese is too high this mottled structure is replaced by a coarse graphitic structure. This is illustrated by two analyses. The bodies were 6-in. thick: A (Table VI) was a close mottled structure that gave very satisfactory results in all the 20 cylinders required: B analyses gave a fracture open and not mottled and the cylinder was not satisfactory. Manganese was too high in the defective cylinder, which accounts for the low combined carbon and soft character of the mixture. Without doubt this cylinder would have been satisfactory if the manganese had been lower."

Table VI.—*Loudenbeck's Results.*

	T.C.	C.C.	Si	Mn	S	P
A	3.34	1.44	0.90	0.25	0.136	0.39
B	2.98	0.65	0.71	0.49	0.120	0.31

From the report in Genie Civil on ingot moulds it would appear there are two critical percentages of manganese to stand up to heat treatment. The usual specification was to limit ingot moulds to 0.6 per cent. M. Groselaude found he obtained a rise in the number of casts made up to this figure of 0.6 per cent. with a maximum of 110 casts, then there was a sudden drop to below 20 casts with manganese at 0.8 per cent. This low figure continued until about 1.6 per cent. manganese was present with an average of 140 casts. With manganese 1.75 to 2.25 per cent. the average over two years was 175 casts. With further increases, the number of casts dropped rapidly.

Smalley's results on "Heat and Scale Resisting Cast Irons" might be quoted, although as these were white irons, they are rather outside the subject. His conclusions were that manganese (1) Reduces the resistance to scaling; (2) increases graphitisation; and (3) decreases strength, and should not exceed 0.30 per cent.

These examples have been put forward because of the excellent results obtained by Carpenter, Matsuura and Donaldson with high manganese irons showing special resistance to growth and giving good physical properties up to 500 deg. C. As all these results were obtained on small bars, it might be advisable to try out the behaviour on thicker sections, such as are found in Diesel liners.

Sulphur.

Before touching the manganese sulphide question, it would be well to consider the effect of sulphur. That sulphur is injurious to steel as FeS is accepted at once, the great variation in the freezing point leading to the well-known structure, but in cast iron even with manganese as low as 0.2 per cent. and sulphur as high as 0.2 per cent. (which is as low and high as ever found in ordinary cast iron) no clear proof has ever been submitted showing the evil effect of FeS as such. Coe states: "The transverse strength, tenacity and hardness are increased by the addition of sulphur." Wüst and Miny state: "The tensile and transverse strengths and resistance to impact of low manganese irons are not impaired by sulphur"; "In all cases the hardness is increased by the addition of sulphur independently of whether it is present as FeS or MnS." Rhead, Cook, and Hamasumi also agree. Rowe states: "Experience has shown that it is extremely difficult to get iron of high strength with abnormally low sulphur." Neither Cook, Coe, nor Hamasumi found any difficulty with fluidity if cast at a high temperature. The last named found the tensile was 1.3 to 2.5 tons higher when cast at 1,400 deg. C., instead of 1,350 deg. C. Neither has the author experienced any difficulty in running metal with S, 0.25 per cent.; Mn, 0.35 per cent.; not so much as with carbon down to 2.5 per cent. Table VII gives some of the results.

In view of the above facts it is difficult to account for the oft-made statement concerning the cause of the weakening effect of FeS *as such*, in the amount found in grey iron. Is this not another effect of steel theories? Personally the author has never seen FeS in any iron with 0.2 per cent. S and 0.2 per cent. Mn, neither has he ever met anyone who could produce a photo or sample showing FeS with sulphur below 0.2 per cent.; certainly not as a band surrounding the crystalline structure as in steel.

Bolton, in a Paper before the American Foundrymen's Association, states; "In the author's experience he has never been able to find any evidence of sulphur network, and the idea that fracture depends on sulphur network is a myth."

From what has been said it may be concluded that sulphur in cast iron is only harmful when it is present in such amount as to give an excessive quantity of free cementite or when other elements such as silicon have to be increased to neutralise this effect and reduce the combined carbon to a reasonable figure; otherwise sulphur under control is of great value as a strengthener and grain refiner.

If from any cause such as heavy steel additions, such as are used in "Emmel" or "Meehanite,"

Table VII.—*Influence of Sulphur.*

Authority.	T.C.	C.C.	Si	Mn	S	P	Trans. strength lbs. on bar 12″×1″×1″	Deflection in inches.	Tensile strength. Tons per sq. in.	Hardness No.
Coe ..	2.79	1.06	2.24	0.016	0.016	0.027	2,240	0.080	9.92	*45
Coe ..	2.90	1.06	2.24	0.016	0.104	0.027	3,125	0.114	13.04	*45
Coe ..	2.70	1.13	2.37	0.016	0.180	0.027	3,994	0.150	21.02	*43
Hamasumi	2.90	0.79	1.77	0.02	0.049	0.01	—	—	21.04	†210
Hamasumi	2.84	0.74	1.76	0.02	0.087	0.01	—	—	23.00	†223
Hamasumi	2.85	0.81	1.82	0.02	0.120	0.01	—	—	22.09	†226
Hamasumi	2.80	1.04	1.87	0.02	0.176	0.01	—	—	21.05	†241

*Shore. † Brinell.

one is nearly forced to have a high sulphur, there are two ways to reduce the combined carbon. First, to increase the silicon or both carbon and silicon, in which case a little strength is gained, owing to the coarser primary graphite and pearlite, also the resistance to growth at moderate temperatures is decreased; or increase the manganese, thereby rendering part of the sulphur passive as MnS, while the excess manganese acts as a degasifier, grain-refiner, and gives life as shown previously.

Manganese Sulphide.

It is also difficult to understand the oft-made statement that with a ratio of even seven of manganese to one of sulphur that the whole of the sulphur is in the MnS condition. How is it that even with this ratio, if the sulphur in the charge is raised, leaving the other elements the same, the resultant castings are harder and the combined carbon higher? The same effect takes place if the sulphur is increased by adding it down the spout of the air furnace. The resultant rolls will be deeper in chill. There are thousands of tons cast under these very conditions, taking from five to six hours to set, so if it is stated that equilibrium conditions have not been attained, the author is not interested, as it is evident they never would be under ordinary foundry conditions.

There is no doubt that sulphur exists additionally to MnS in association with the carbides either in solution or as a ternary eutectic. With regard to MnS (a weak, brittle material, "rotten as a carrot," according to Stead), its addition can only be considered as the lesser of two evils. Fortunately, its volume is never large, but being nonsoluble in molten iron, it may segregate in important spots and cause damage out of all proportion to its volume.

Young, speaking of manganese-sulphur balance, states: "Certain Diesel cylinder liners came to a most disastrous ending through that very cause, the failure being a mystery to everyone, until the unbalanced sulphur and its effect were discovered." Coming from such a source, it is a pity the author did not take his audience more fully into his confidence, giving analyses, micros, and his interpretation of their import, for the result would have been of great value to many. Unfortunately, most founders are obsessed with one idea, and sometimes fail to see the other points. The series of analyses (Table VIII) given by Young are not too

TABLE VIII.—*Young's Results.*

T.C.	Si	Mn	S	P	Mn to S ratio.	Lbs. Trans. strength on bar 12"×1"×1"
3.45	1.62	0.27	0.122	1.08	2.2 to 1	1,747
3.43	1.47	0.23	0.231	0.60	1.0 to 1	2,341
3.37	1.56	0.28	0.137	1.21	2.0 to 1	2,352
3.47	1.47	0.41	0.220	0.61	1.9 to 1	3,528
3.38	1.73	0.58	0.112	1.14	5.2 to 1	3,662
3.41	1.05	0.51	0.129	1.05	4.0 to 1	3,786

convincing, but as the combined carbon is left out, it is hard to come to any conclusion. It could be held the last two gained strength from the excess manganese. He also states in the same Paper: "It is possible, even probable, that sulphur and manganese together are the most vital combination in cast iron."

Unreliability of Evolution Method of Sulphur Determination.

Before leaving the sulphur question it would be well to give another warning concerning the unreliability of the evolution method with moderately high sulphur. The author could seldom obtain check results by the two methods, nor could several outside firms when asked to check his results.

Recently Crome tested 40 samples by both evolution and oxidation methods. In ten cases, both methods gave near results. In 19 the results varied 50 per cent., the remaining 17 fell between the two extremes. Stating there was a popular idea that by annealing the correct result would be obtained by the evolution method, he tested 15 samples after annealing, by both methods. The results were remarkably close, but instead of agreeing with the original oxidation value, they checked with the original evolution result. An amount of sulphur equal to the original difference had been lost. Whether this fact has anything to do with the difference in the behaviour of the MnS and FeS in the Baumann test might be investigated.

Crome states, "In spite of the same period of reaction, the same acid concentration, and conditions otherwise equal, and particularly the same sulphur content, prints were coloured much darker by the MnS than the FeS; obviously the solubility of MnS in acid is greater than FeS."

Phosphorus.

Phosphorus is definitely known to be injurious to steel, but its effect on cast iron is not so clear. Stead, Hatfield, and others have investigated the ternary alloy iron-carbon-phosphorus and there is a fair knowledge to this extent, but no work has been done with the remaining elements added, except some experiments by the Japanese with silicon present.

The whole trend of modern work has been to limit the phosphorus to about 0.3 per cent., the limit of solid solubility. On the other hand, from a list prepared from all sources there is no doubt high tensile results are obtained with up to 1 per cent. phosphorus.

Both Lowry and Piwowarsky say that phosphorus shows an increased resistance to wear with increasing phosphorus up to 0.9 per cent., while Lehmann from service conditions on brake blocks, comes to the conclusion that phosphide eutectic has a harmful influence on the wear, as it tends to form a grinding substance. Young also states that "Corrosion by sea water is hastened by increase of phosphorus." From personal experience, over a period of 15 years with about 50 tests per week, it was proved that with increase of phosphorus the relation between the transverse and tensile altered, the transverse and deflection result decreasing with increase of phosphorus. This was confirmed by Field, Hyde and others, and also by the list of collected analyses. One of Wheeler's is given as an example in Table IX.

TABLE IX.—*Influence of Phosphorus.*

T.C.	C.C.	Si	Mn	S	P	Lbs. Transverse strength.	Tensile strength Tons.	Brinell Hardness No.
3.05	0.75	1.27	0.47	0.07	0.75	3,767	15.2	228
3.08	0.63	1.41	0.43	0.10	1.04	3,472	15.5	228
3.06	0.76	1.30	0.30	0.12	1.30	3,136	15.4	228

The best paper for some years was one by MacKenzie, the result of several years work and comprising some thousands of tests. The discussion which follows was equally important because it touched the vital issues. MacKenzie's conclusions are "That for each type of casting the maximum strength will be found at the lowest phosphorus content compatible with fluidity. For castings where resistance to shock is of importance, low phosphorus irons should be used, but ordinarily no trouble will be experienced with phosphorus running up to 0.8 per cent. if the carbon and silicon are correctly proportioned to give the strength desired."

Smalley took exception to the last point, stating that between 0.25 and 0.8 per cent. of phosphorus is a very delicate and dangerous region of phosphorus in producing differential freezing, and where there is a change of section and the formation of phosphides is thrown out, it tends to cause porosity and spongy places. This is in line with Harley's and other Coventry managers' experiences.

Bolton also pointed out that in grey iron metallurgists assumed that "the eutectic form was the only one occurring in cast iron; that was not so, there is in the lower phosphorus irons a solid solution *steadite*. It is not a eutectic alloy in any sense of the word and can be shown microscopically. It is not until there is about 0.5 per cent. phosphorus in cast irons that are fairly high in pearlite that you get the eutectic alloy."

Cupola Practice.

The exhaustive trials carried out by Rudeloff for the German Ironfounders show the influence of cupola practice—a factor quite foreign to steel making. The object was to ascertain with what degree of certainty similar physical properties could be obtained in a number of foundries using the same prescribed material and working on similar lines. Specialists of acknowledged standing supervised each cast. Despite the use of the same mixture, the results varied widely, transverse figures ranging from 21.5 to 27.5 tons, while the tensile gave values from 10.75 tons to about 15 tons per sq. in. Next each foundry was to aim at a transverse of 17.8 tons, with a deflection of 0.28 inches and an upper limit of 21.6 tons, with a deflection of 0.39 inches with their own mixtures. Here again there were wide fluctuations, the range being 21.5 to 31.3 tons, and from 11.5 to 16 tons. It is difficult to account for these variations under the fixed conditions, and founders in Britain work nearer.

Melting Temperature.

After the investigations of Elliott, Piwowarsky, Kerpely, Emmel and, lately, Homma, there is no doubt that high melting temperature has a great effect on the resultant metal. Most foundry men are familiar with Piwowarsky's results (Homma's confirm these). He made a series of experiments and found that with increased melting and casting temperature he increased both depth of chill and hardness. He then carried out further trials, taking the metal up to 1,500 deg. C., then lowered it to various temperatures and poured, thus by keeping the maximum temperature constant and then varying the casting temperature he showed there is very little change in hardness or depth of chill, so casting temperature may not be the vital matter generally assumed, and the variation in several investigator's results may be due to neglecting to note the tapping or melting temperatures.

There is another side to this issue. Those who have charge of foundries all know that to cast cold leads to hard castings. For instance, Evans of Derby noted that in casting a number of cylinders from one ladle, if there was a complaint from the machine shop regarding hardness of one or two cylinders in that batch, it was nearly in every case the last one or two cast. This is easily explained, being due to the chilling effect of the mould. In going through figures for this paper, the author thus noted more than one investigation, where the given casting temperature was below the liquidus. Those crystals and others formed inside the mould will never go into solution again, and it is futile to expect reliable results under these conditions.

(To be continued.)

Birthday Honours.

We regret that in a paragraph referring to those connected with the foundry trade who received honours in the King's Birthday List the name of Mr. F. J. Taylor, J.P., was omitted. He was awarded the O.B.E. for public services rendered in the Neath area. Mr. Taylor was one of the founders of the Wales and Monmouth Branch of the Institute of British Foundrymen.

Steel Sleepers in South Africa.—The South African Railway Administration, during the past four years, has been using steel sleepers in increasing quantities. These have been found to be more economical on light branch lines and on certain sections of the main system than timber sleepers. Present plans are not to use steel sleepers to the total exclusion of timber, but the Administration favours the former whenever conditions are suited to their use. Purchases of steel sleepers from 1924 to 1927 were valued at £574,843, of which £414,991 worth came from Germany, £140,707 worth from France, and £19,145 from Belgium, but none from Great Britain.

Variables in Steel Foundry Practice.

By F. A. Melmoth, Sheffield.

(*Continued from page* 410.)

INFLUENCE OF PROCESS.

A factor which might be considered under the heading of steelmaking variables is that of the influence of steelmaking process. Theoretically it might be assumed that steels of equal general composition should behave similarly, and give comparable results in the product, irrespective of the process by which the steels are made. Practical experience of material produced by various processes suggests, however, that this is not the case. It appears to the writer therefore that this might be taken as a variable to be considered where steel processes are liable to undergo a change in type.

For heavy work, the Siemens open-hearth furnace practically monopolises the demand, being the only type of furnace at present capable of producing commercially large enough single charges. It is therefore more in the direction of the medium and lighter classes of casting that variations of steelmaking process are likely to occur. The general opinion of many steel foundrymen would suggest that the main point of variation is in the actual behaviour of the steels during casting, that is, in their comparative degree of fluidity, which mainly controls the ease with which a steel casting can be run. In the writer's opinion, which is based on observation over large quantities of steel of each type, the following would represent the order of the various steelmaking processes based on their comparative ability to produce steel with a degree of fluidity high in proportion to its temperature. The crucible is omitted owing to the comparative infrequency of its use at the present time:—(1) Converter; (2) electric furnace (single slag); (3) Siemens open-hearth: and (4) electric furnace (double slag).

In placing electrically-produced double-slagged steel at the bottom of the list, the writer will probably meet with a good deal of opposition. He would emphasise, however, that the steel he has in mind, classified as very low in fluidity, is that produced when the bath is subjected to the action of strongly reducing slags, for considerable periods. When this is the practice the writer has always found that to a greater or less extent, depending on degree and time of the action, fluidity is markedly lessened, and it consequently becomes more difficult to run light sections.

Various suggested explanations have been forthcoming from time to time to account for this variation, and also that frequently claimed between electric and converter produced steels of the same analysis. The present writer's opinion and tentative suggestions were set forth in a Paper given to the Lancashire Branch of the Institute of British Foundrymen some time ago, and in order not to unduly prolong the present Paper he would refer those interested to this publication. It will perhaps suffice to say that the writer has seen no reason to modify seriously his opinion since the date of the Paper referred to.

A good deal can be said with regard to the influence of steelmaking process on the regularity of the composition of the castings produced. The electric furnace with a basic hearth stands pre-eminent in this respect, its freedom from slag losses making it a fairly simple matter to maintain regularity of analysis well within practical limits.

When producing certain special classes of work, notably those calling for alloy steels, variables from the composition standpoint cannot be countenanced, owing to the significance of the alloying element on the ultimate service performance of the casting. It is here that the real benefit of electric melting can be truly appreciated. It is perhaps fair to say that there is no special element used in such steels which is not under more perfect control in the electric furnace than in any other type. With correct slag conditions, which are attained without difficulty, quantities in the casting become merely a question of calculation, as losses are practically negligible. The production of straight carbon steels accurate to analysis is almost as straightforward a matter in the Siemens open-hearth as in the electric furnace, and in this class the latter furnace cannot demonstrate any serious advantages.

In the writer's experience the converter, while producing a steel very suitable for light castings, cannot be said to attain the regularity of product obtainable from the other two processes mentioned. This is probably due to the fact that the critical period of the blow, which controls very largely both character and composition of the product, is both very short and also entirely in the control of the human deciding factor. This calls for both high skill and long experience if regularity is to be assured.

Deoxidisers.

Associated with steel production, and certainly having an influence as a variable, is the use of various deoxidisers other than the silicon and manganese content normally present. The use, or, more important, the abuse, of such materials, can induce effects in the casting of quite a serious order. At the risk of being accused of platitude, the writer would emphasise that these useful materials should never be permitted to become apparent remedies for bad steelmaking practice. They are in no case capable of turning badly made steel into good steel, and their use in such circumstances often produces a condition in the casting which is positively dangerous.

Aluminium.

Taking first the case of aluminium, the writer considers it quite possible to produce perfectly sound castings without its use. On the other hand, he has always used it in moderate amounts as a safeguard, principally in green-sand castings. He is satisfied that if added in small amounts to previously well made steel, aluminium tends to confer on the steel a certain degree of capability to resist the unbalancing effects of mould gases and water vapour. A charge of steel of a rising nature cannot be safely corrected with aluminium. In such a case large amounts are called for, and the oxidation of the aluminium produces a dirty steel, and ultimately castings much reduced in strength. Such charges should invariably be returned to the furnace and corrected in a proper manner.

Apropos to the use of aluminium, the writer has often seen it used by placing pieces in the mould, it being intended that the steel should take it up during its passage through the mould. If this is done it is necessary to be sure that the pieces are very small and thin. An experience some years ago has made the author very chary of introducing aluminium in this way. Certain castings showed extremely hard spots on the bottom face as cast, and it was impossible to machine them satisfactorily. The steel being satisfactory in composition and structure, and the position of the hard spots making it impossible to contemplate segregation, the matter called for investigation. It was found that porosity had been experienced on this bottom face, and with a view to preventing this quite local defect, small pieces of aluminium were placed in the mould. The hard spots were cut out and examined, and it was found that they contained anything from 10 to 20 per cent. of aluminium. It seems feasible that the chilling effect of the green sand mould had been sufficient to solidify the steel in contact with the mould before complete diffusion of the pieces of aluminium could take place, with, of course, the production of a hard alloy of iron and aluminium.

Ferro-Titanium.

Ferro-titanium of both carbon-containing and carbon-free types is often used in steel for castings. The writer has only used this material in castings made from electric furnace steel, and if added to the furnace and thoroughly absorbed by the bath before tapping some small benefit in the strength of the product was noticeable. Its cost compared to the benefits achieved did not, however, permit of its regular use, as it was considered that equally good results could be obtained at much less cost. In any case, it was considered essential to add it in the furnace, and not in the ladle.

Calcium silicide is another material very commonly used as a final deoxidiser. Its use in moderate quantities is undoubtedly useful, but the remarks regarding the use of aluminium apply also in this case. All the materials, while representing useful special additions to steel, are in no way capable of nullifying the effects of poor steelmaking practice, and the degree of their use might even be taken as a measure of the perfection of the steelmaking methods employed.

Heat Treatment.

When it is appreciated that no work can be placed on a steel casting with a view to breaking down the coarse cast structure commonly present before heat treatment, it is realisable that this operation is capable of producing many serious variations if inefficiently carried out. Almost all steel castings are submitted to treatment nowadays, and their ultimate capabilities can only be really produced by a correct procedure in this operation.

The bulk of general engineering castings are made from mild steel, which in its cast form, slowly cooled in a sand mould, exhibits a coarse, strongly crystalline structure. As might be expected, such a condition is coincident with physical properties of a comparatively low order, and very small resistance to shock.

The following is a typical test result of such a mild steel in its sand cast form:

Max Stress. Tons per sq. in.	Yield Point. Tons per sq. in.	Per cent. Elongation on 2 in.	Per cent. Reduction of area.	Cold Bend.	Izod Impact. Foot pounds.
29.8	15.0	14	18.58	87 deg. broken	15

Such material does not represent a satisfactory product for the bulk of engineering requirements. The figures below are from tests from the same charge taken after a perfectly straightforward annealing process at 875 deg. C. followed by cooling in the furnace.

Max. Stress. Tons per sq. in.	Yield Point. Tons per sq. in.	Per cent. Elongation on 2 in.	Per cent. Reduction of area.	Cold Bend. 1 in. diameter.	Izod Impact. Foot pounds.
31.2	16.6	26.5	31.58	180 deg. unbroken	36

It will be seen at once that a very great improvement has been brought about. Examining the figures in relation to the micro structure will show that the removal of the coarse angular crystalline structure has resulted in a large increase in the ductility of the steel, and in its resistance to shock.

A short study of this very simple case will doubtless be sufficient to emphasise the necessity for lack of variation in such an important operation. The real physical capabilities of a steel either of the straight carbon or alloy type are never exhibited in its cast form, but are only potentially present, able to be evolved by correct heat treatment. Such treatment will, of course, vary according to the nature of the steel composing the casting, and to some extent also according to the service demand made upon it.

The great majority of specifications for mild steel castings can be easily met by a straight annealing, cooling either in the furnace, or in air, the latter depending principally on the type of

casting being handled. Castings with heavy sections would obviously be very liable to fracture if quickly cooled, and these are almost invariably cooled in the furnace. The lighter types, however, can safely be cooled in air, resulting in a somewhat higher tensile strength and yield point, while ductility remains practically unaffected. If complicated in type, air cooling can be followed by a second heating to a lower temperature, say 600 deg. C., with advantage.

While such a treatment will enable any initially good material to conform comfortably to standard specifications, the limits of the capabilities of the steel are not by any means reached. In certain special cases, and where size and design of casting permit, a marked further improvement is obtained by quenching the casting in water or oil from 850 to 900 deg. C., afterwards repeating to a lower temperature, say 450 to 600 deg. C., depending on the properties desired.

These remarks apply with considerably greater force in the case of alloy steel castings. The real benefits of the presence of the alloys can only be attained by a correctly designed method of heat-treatment. Taking the case of a nickel-chrome steel as an example, the best result from this material, quenched in oil from 850 deg. C. and afterwards reheated to 550 to 600 deg. C., gave the following:

Max. Stress. Tons per sq. in.	Per cent. Elongation on 2 in.	Per cent. Reduction of area.	Cold Bend. ¾ in. × ⅜ in.
52.3	24	52.4	18 deg. unbroken.

A test of this high standard is, of course, out of the question unless the casting is subjected to a carefully designed and controlled treatment, and the figures are given as a matter of interest, and to show that even in casting form, subjected to no mechanical work of a structure-refining nature, such steels are capable of being put into a remarkably satisfactory condition by heat treatment alone.

Manganese steel, as is well known, depends entirely upon the efficiency of its heat treatment to exhibit its unique properties, and no matter how good the initial material, no success is possible with this product until its treatment is thoroughly understood.

These somewhat sketchy remarks on heat treatment are given with the idea of adding emphasis to the importance of correct treatment, so that the real necessity of suppressing variables will be appreciated. The writer is aware that, even to-day, founders not able to avail themselves of expert metallurgical knowledge are liable not to attach full importance to the operation, with the result that their product can never exhibit its best capabilities.

The main function is obviously temperature, and as detrimental results follow either too low or too high temperature of treatment, these are the first variables to be avoided. This can only be done regularly and satisfactorily by correct temperature control by means of modern instruments. Accurate pyrometers, correctly placed to indicate the real temperature of the material itself, and not the furnace atmosphere only, are an essential.

The length of time required is controlled by the thickness of section involved, and variations in result are not uncommon from a lack of appreciation of this fact. Faults which can be directly attributable to incorrect manipulation during treatment can be tabulated as follows:—

(1) *Too low a temperature.*—The coarse "as cast" structure is not completely removed, and the physical properties are very little affected as compared with those of the untreated product. The solution of the cast structure, and its recrystallisation in a much finer form, can only be attained by temperatures above the upper recalescence point of the material.

(2) *Too high a temperature.*—The cast structure is removed, but as the coarseness of the final structure is largely dependent on the temperature from which the casting last cooled, its structure will be now much coarser than necessary, and its physical properties correspondingly lowered. In addition, the castings will be badly scaled, and probably distorted.

(3) *Too short a period at temperature.*—The time required is controlled principally by the thickness of section involved, and the result of too short a time for a given section will be that the solution of the cast structure will not have proceeded to completion. The remaining strongly crystalline and angular structure will cause the casting to possess physical results lower than the true capabilities of the material.

Apart altogether from the changes in microstructure, with coincident improvement of physical properties in the casting, there are two further directions in which possible variations of result may take place. The first is that of the action of heat treatment in the removal of stress existing in the casting as received from the mould. These stresses can be of a two-fold character, the first being those induced by variations of section thickness and consequently locally varying cooling speed in the mould, and the second, the stresses resulting from hindrance to the normal contraction when cooling from the molten condition. In effect these may be taken as identical in their action, which, briefly stated, is that they cause the casting to contain, locked up in its crystalline structure, stresses of varying degree, liable as a result of shock or sharp changes of temperature to fracture the casting. The coarsely crystalline structure, possessing very definite lines of cleavage, is susceptible to fracture from this cause, and the refinement by treatment renders it much less likely that stresses will release themselves by fracture. In addition, the slow and even cooling associated with the annealing of heavy or complicated castings removes these stresses to a vary large extent.

A variable, not always easy to control in such cases, is the increasing to the danger point of the stresses by uneven or too quick rise of temperature in the heating up process. In many types of steel, this can very easily result in fracture. With such castings it is always safer to put them into the furnace before becoming cold after casting. By this means, and by careful and reasonably slow heating, to avoid sharp temperature potential between inside and outside, or between one part and another, it is usually possible to eliminate the risk of fracture. Obviously, the more brittle the cast condition of any particular type may be, the greater is the risk of mishap from this cause.

Although the microstructure may be perfectly changed from the coarse crystalline as cast condition to the finer and less angular and consequently more ductile state by submitting the casting to the correct temperature for a sufficient length of time, it is not necessarily in an unstressed condition. The bulk of the stress removal portion of heat treatment depends upon the cooling period. If this is so fast that section variation can cause material differences in temperature from part to part, unequal cooling stresses are bound to occur. In small castings their effect may be negligible, but in heavy castings it is essential that cooling is perfectly under control, and proceeds slowly and evenly. In some cases it is necessary that this is carried down at this rate to almost atmospheric temperatures, and serious fractures have been recorded when such castings have been removed from the furnace, at a period when the outside appeared to possess no noticeable degree of warmth.

A further feature associated with treatment, but only common in large complicated castings, is that of distortion. During the comparatively long periods these castings are at a high temperature there is always the possibility of distortion by sagging, and very careful packing is necessary to ensure support. Distortion can also be caused by uneven heating, and the writer has known long thin castings badly affected by one side being more exposed to the source of heat than the other. The present Paper does not claim to have exhausted by any means the possibilities of variation which exist in steel-foundry practice, but has perhaps indicated sufficient to show that almost eternal vigilance is called for in the manufacture of steel castings if regularity is to be obtained and maintained. Some of the points raised may also indicate directions of investigations with a view to their elimination, or at any rate, the minimisation of the frequency of their occurrence.

Aluminium Casting Alloys.

A REVIEW OF RECENT PROGRESS.

By GEORGE MORTIMER (M.INST.BRIT.F.).

(*Continued from page* 432.)

An alloy of the 4 per cent. Cu class with 2 per cent. Si added is readily cast and heat-treated, and is becoming known, particularly in its worked forms, under the name of Lautal. Lithium has much the same effect as magnesium, forming a silicide with a solubility varying with temperature: Lithalium and Scleron employ lithium in place of magnesium. The alloy Scleron is almost identical in composition with the familiar 2L5, with the addition of 0.6 per cent. Mn and 0.1 per cent. Li. A number of such heat-treatable alloys, stiffened up with zinc, are in existence and much used in constructional work: the author finds that the weakness of the zinc alloys at high temperatures militates against their wide use in the cast, heat-treated state.

All of these alloys call for somewhat prolonged soaking in the sand-cast state, an economic factor which has encouraged research in the direction of some element which would enable higher soaking temperatures to be used with safety, or would improve the solubility of the hardening compound. An an example, Hyman * has developed an alloy containing Cu, 0.3; Ni, 0.6; Fe, 1.75; and Mg, 0.5 per cent. In the sand-cast bar this alloy will give 16 to 17 tons tensile with 5 to 7 per cent. elongation, after only one hour's soaking at 595 deg. C., followed by quenching in oil. An alloy of this composition might be expected to give a certain amount of trouble in founding, and the very high temperature of treatment may cause difficulty with intricate commercial castings. This, however, remains to be proved: the alloy is worth quoting here as a useful development in the direction of briefer and cheaper heat-treatments. The high treatment temperature is probably made possible by the formation of complex iron-nickel-aluminium compounds, the presence of which raises the solidus. Nickel itself tends to do this, and in addition has the useful property of increasing the solubility of $CuAl_2$. The most widely used heat-treated casting alloy in this country is still "Y" alloy, which, in addition to the usual 4 per cent. copper, contains 2 per cent. nickel and 1½ per cent. magnesium.

"Y" alloy possesses elastic and high-temperature properties which compensate for certain inherent foundry difficulties, and the steadily growing demand for this alloy for parts like pistons, particularly for very large Diesel-engine pistons, justifies a more detailed description of its peculiarities and the foundry methods needed.

Alloying.

Copper is added in the usual 50: 50 alloy, made by melting the required amount of copper and adding aluminium to it a little at a time. Nickel is generally added in the form of shot to form a 20 per cent. nickel "hardener," which is added to the main melt. When using this method of making the hardener there is always the possibility of the nickel shot dissolving away to a pin-point, and then forming with the molten aluminium an almost insoluble compound, which will probably turn up later in the casting as a "hard spot." Hard spots are the bane of "Y" alloy and there are many varieties: if possible it is well to eliminate them seriatim from the start. Several different methods have been devised for the better introduction of the nickel, a good one being the introduction of nickel and copper together. The author has had good results by purchasing a two to one cupro-nickel rod from a reliable source, and stirring the aluminium with it until the requisite amount has washed off it.

Magnesium is added last, and quite simply. Provide a small crucible pierced at the Si, and attach it to a stirring rod in an inverted position. The correct weight of magnesium is thrown on the surface of the melt, and is immediately thrust to the bottom by the device described, when it will at once melt and can be stirred in. If it is allowed to rise to the surface it will merely burn away.

(*To be continued.*)

* "The Properties of Some Aluminium Alloys." H. Hyman "Jour. Inst. Met.", No. 2, 1925.

XUM

Institute of British Foundrymen.

NEWCASTLE BRANCH ELECTS OFFICERS AND DISCUSSES FOUNDRY PROBLEMS.

At the Annual General Meeting of the Newcastle Branch of the Institute, Mr. Colin Gresty was elected as President for the next session; Mr. Robert Smith, of South Shields, Senior Vice-President; and Mr. Arthur Logan, Junior Vice-President.

Mr. J. N. Simm was elected treasurer, and Mr. H. F. Parsons, Mr. J. D. Carmichael, and Mr. F. Robson, members of council. Mr. F. Sanderson was re-elected Honorary Secretary.

Mr. J. N. Simm and Mr. Victor Stobie, the retiring President, were elected as representatives on the General Council. Mr. Robert Smith and Mr. Logan were appointed auditors.

With regard to the John Surtees Memorial examination, Mr. Stobie announced that unfortunately Mr. Carmichael, the Chairman of the Governors, was unable to attend the meeting that evening owing to ill-health. He had, however, sent a statement which sought to impress upon all the members of the Branch the importance to themselves and their profession of taking an active interest in the competition. The medals and prizes, apart from their intrinsic value, were, to those to whom they were awarded, tokens of ability, or at least evidence of a close rather than a casual application to the study of foundry practice. The examination was a very thorough one, being conducted by experts in their own department, in the case of the examination just held, in the subject of mathematics and theory by Mr. Forrest, extra First-class Engineer under the supervision of Mr. Cullen, M.A., Wh.Sc., Principal of the Marine School, South Shields, and in the practical methods of moulding and casting by Mr. J. W. Frier, Past-President, assisted by Mr. W. Betham, Member, to each of whom their best thanks were tendered for their patient and scrupulous discrimination of the varying merits of the several candidates.

The object of the memorial as contained in its constitution was to train their members to produce sound castings every time, incidentally qualifying themselves to solve the innumerable difficulties met with in every foundry. To accomplish that high standard of proficiency it was essential that the producers themselves must be willing to devote time to a study of the more remote aspects associated with the most interesting, and, in his opinion, the most important section of engineering or machine construction.

He would urge those eligible for the competition to enter the "Lists," for he was sure that the effort of preparation and knowledge gained thereby would arouse their interest and whet their appetites for still further progress into metallurgy and chemistry, which must be the ultimate aim of the foundryman who would aspire to the successful management and conduct of a foundry.

He further stated that the examiners had always in mind that whilst it was essential to produce sound castings it was equally imperative to produce them by sound commercial and economical methods, and rightly so if they as Britishers were to retain, or, perhaps he ought to say regain, the reputation of being the universal purveyors of ships and machinery for all purposes.

Prize Winners.

Mr. Stobie presented the silver medal and a book to Mr. John Richardson Charlton, the winner. The other prize winners in order of merit were Mr. Edward Christie, Mr. Albert Tennant and Mr. Alfred Richard Kirby, who each received a set of drawing instruments and a book on foundry practice.

Foundry Problems.

MR. PATTERSON, who opened the discussion, took the opportunity of asking a few questions about blacking. He would like to have a mixture of blacking so controlled that he could rely upon it being the same always, meaning, of course, for dry-sand moulds. He found that some moulders had their own ideas of blacking and would not say what they put in their mixture, some putting paraffin in and others something else. Some of these mixtures were good and others were not. He wanted to know, if possible, what ought to be put in the mixture, and the correct proportions. Blacking was a very important factor which had been brought very forcibly to his notice through having had a bad cylinder recently, due to a thin blacking scab, about the size of a shilling, all over one area.

MR. SIMM said that it was a well-known fact that if anything went wrong blacking was the first thing to be blamed. If the matter were investigated it would probably be found that the man who had been on the job had not thoroughly understood his work. Very often clay wash of the wrong consistency would be used, some men testing it by dipping a piece of glass in, and others liking to see a tinge of yellow in it; in other cases they got lime in, which spoilt the clay wash.

MR. MOLYNEUX said that he had overcome scabbing by making a mixture of blacking and keeping it in a tank large enough to contain a supply for one day's work. He always supervised the mixing of the blacking, and when possible it was kept in suspension by blowing air through it. Blacking scabs were now almost unknown in their foundry. The mixing was centralised, and one man was made responsible for it. The mixture was tried for specific gravity, and checked by means of a hydrometer.

MR. PAULIN said that the question of blacking was often discussed, and judging from what Mr. Simm had said a great deal of trouble arose from the variations in clay. He thought that china clay would probably be of a more uniform consistency than ordinary clay wash.

MR. ALLAN confirmed Mr. Paulin's opinion from his own experience, and added that a better skin was obtained with china clay than with ordinary clay.

MR. A. LOGAN said that although he had not gone into the question of china clay, he would say that it had more consistency. He could confirm what Mr. Patterson had remarked about the variability of blacking. The question was one that the B.C.I.R.A. was examining at the present time.

MR. PATTERSON said that they used the same clay for cupola daubing, and it had been a very successful refractory, the reason being that the clay used was of a very fine quality. He thought that the same good qualities ought to apply in a blacking mixture. He would like to know if anyone could give him definite quantities for making blacking with ordinary local clay.

MR. GRESTY asked Mr. Patterson if he was sure that the trouble arose from the blacking and was not sand trouble. Might it not be due to particularly hard ramming? If the scabbing were due to the clay wash it was hardly likely that it would be localised.

MR. PATTERSON replied that the scab was only the thickness of the blacking. He had found out that the man who usually mixed the blacking had induced another man to do it, and he had used too thick a clay wash. He could not definitely say that the blacking was the cause. When the cylinder was smashed it was found that it would have been perfect, as the scab had not penetrated. On being asked if it was not the way in which the blacking had been put on, Mr. Patterson replied that the usual man had put it on. It was also suggested that the scabbing was caused by the moulder putting the blacking on a second time on spots where the first coat had dried.

MR. SHAW said that in his opinion it was necessary for blacking to be standardised so that foundrymen could tell exactly what they were buying.

MR. GRESTY agreed with Mr. Shaw that standardisation of blacking was needed. By an ash-determination test it could, of course, be discovered how much the blacking had been adulterated, but in analysing blacking the actual material with which it had been adulterated was important.

MR. ROBERT SMITH said that he had had the same trouble with blacking, and had complained to the agent from whom he had bought it, and had been told that the blacking was too new, and that if it had been kept longer it would have been all right.

MR. SIMM said that he knew personally that within the next year or two there would be a standardised blacking.

Rod Feeding Problems.

MR. PATTERSON said that he had had a case where, by some oversight, the heads of a casting, cast with hot metal, were closed within about a quarter-of-an-hour of casting. The casting was perfectly good, although only fed for a short time. Another one of the same pattern was fed for an hour, but was not so good. He had found that a dull cast casting took more feeding.

MR. SMITH said that it might have depended on the way it was fed.

MR. STOBIE, with reference to Mr. Patterson's remarks upon the dull cast casting, said that he had found that exactly the opposite was the case with steel.

MR. GRESTY said that one thing which might explain why a dull cast casting took more feeding was that if dull metal was used for casting signs of the lack of feeding might not be seen when the head was cut off, but they would most likely be deeper seated. Cooler metal was bound to give rise to less shrinkage. If they could not see the actual shrinkage they would think that it was not there, but if the casting was broken up it would probably be revealed.

MR. BROWN said that he would like to know how far the feed rod ought to go into the mould, whilst MR. SMITH gave it as his opinion that the rod ought to go as far down as possible. MR. BROWN replied that it was his own contention that it should only go about 3 in. into the casting.

MR. SHAW said that he thought the rod had to be put in in proportion to the mass of metal feeding, then it ought to be gradually withdrawn as the feeding progressed. If the metal had a short freezing range and was cast very hot with thin gates, a sort of solidification was going on all the time. It was remarkable what small heads could be put on if the correct material was used.

Pencil Gates and No Risers.

MR. PATTERSON said that he remembered that M. Ronceray had described how he had cast a 9-ton roll without any risers. He rather fancied that the roll was run in at the bottom with a very small gate, and very hot metal used.

MR. MOLYNEUX said that he had made experiments with pencil runners, and had found it impossible to cast without risers, unless pencil runners were used. He thought Mr. Kirby would confirm what he said.

MR. STOBIE thought that possibly there was some misconception as to the effect or operation of a header. The pressure exerted by the head depended on its height, and not on its weight or size. Therefore, having a high head was not necessarily an advantage unless its cross-section was large enough to allow the metal to remain liquid longer than the casting itself.

MR. ALLAN said that when the problem of gating a casting was solved, the problem of most of the bad castings would also be solved. He had an instance in mind of a job where they had made about 200 castings from the same pattern, there being very few of them wasters. A few months ago they had had to replace two of these castings and they had made a dozen before they had got two good ones, the conditions being exactly the same in each case. They had eventually come to the conclusion that the gating was the trouble, as the size and position of the runner had been altered.

MR. GRESTY said that that proved that when successful practice was established the actual gates should be made part and parcel of the pattern. Of course, that could not be done with all castings, but in many cases it could be done with advantageous results.

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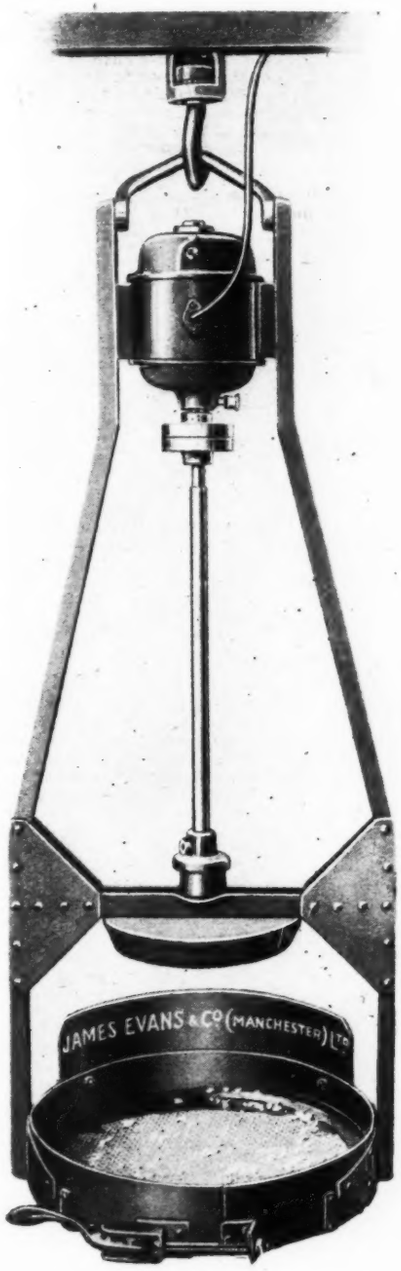

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Trade Talk.

THE ADDRESS OF the Knutton Iron & Steel Company, Limited, is now Knutton, Stoke-on-Trent.

MESSRS. RUFUS MANN & COMPANY, LIMITED, electrical and mechanical engineers, have removed to 23, Oxford Street, Glasgow.

THE WAGES REGULATED by the sliding scale under the Midland Iron and Steel Wages Board have been reduced 2½ per cent. for the period June 4 to August 4.

ACCORDING TO A MESSAGE from Prague, a net profit of £250,000 was reported at the annual meeting of the Skoda Iron Works. A dividend of 17½ per cent. has been declared.

THE ASSOCIATION FOR EDUCATION IN INDUSTRY AND COMMERCE will hold its annual conference in London on June 12, 13 and 14, at the Regent Street Polytechnic.

MESSRS. SARCO COMPANY, LIMITED, recording instrument makers and engineers, have removed from 124, Long Acre, to larger workshops and offices at 133, Long Acre, London, W.C.2.

THE CLAIMS of gantry men and annealers in the tinplate trade were considered at a special meeting of the sub-committee of the joint standing committee at Swansea recently.

MESSRS. PETTERS (IPSWICH), LIMITED (formerly Vickers-Petters, Limited), are closing down their Ipswich works and are concentrating production on the parent works at Yeovil.

MESSRS. SIR W. G. ARMSTRONG, WHITWORTH & COMPANY, LIMITED, have launched the twin-screw buoyage and survey vessel "Dayspring" for the Government of Nigeria.

A TENDER for a 12,500-kw. turbo-alternator and condensing plant costing £46,251, submitted by the Metropolitan-Vickers Electrical Company, Limited, has been accepted by the Stoke-on-Trent Electricity Committee.

MESSRS. CHRISTMAS & WALTERS, LIMITED, have just received orders for R. D. Wood gas machines for the Birmingham and Birkenhead districts. They will be of their heavy-duty type, gasifying over two tons of coal each per hour.

A REPORT FROM Jamshedpur states that, owing to the continuance of the strike of their workers, the board of directors of the Tata Iron & Steel Company have decided to shut down their works and to declare a general lock-out.

SHIPBUILDING ON THE CLYDE has shown a decided improvement during the past month. In all, 28 vessels of 49,461 tons were launched during May, making a total output of 87 vessels of 240,732 tons for the first five months of this year.

OWING TO A DECLINE of 7s. 2d. per ton in the average net selling price of manufactured iron in the North of England, a 5 per cent. reduction in wages has been put into effect as from May 26. The reduction is applicable to puddling and other forge and mill wages in conformity with the sliding scale.

IT WAS REPORTED at a meeting of the Tees Conservancy Commissioners that Synthetic Ammonia and Nitrates, Limited, Billingham, had submitted plans showing riverside works proposed to be constructed in connection with a cooling water pumping scheme. The Commissioners gave their consent to the plans.

THE NUMBER OF blast-furnaces in blast on the North-East Coast has been reduced from 38 to 37 by the decision of the Linthorpe Dinsdale Smelting Company, Limited, to blow out one of the Dinsdale furnaces making spiegel. A similar development is possible at the Carlton Ironworks of Messrs. Dorman, Long & Company, Limited, where the one furnace at present active is making ferro-manganese.

A GROUP of 26 American machine-tool and supply manufacturers has made arrangements for co-operative selling in British India. Mr. C. Warren-Boulton, of Calcutta, India, has been appointed exclusive representative for a term of years after spending several months in the United States at the works of the companies he is to represent. While the group is not finally closed for new members, there is no intention to expand it materially.

THE STANDING COMMITTEE (GENERAL MERCHANDISE) appointed by the Board of Trade will hold their inquiry as to whether pumps of all descriptions and parts thereof should bear an indication of origin, at 11.30 a.m. on Monday, July 9, and at 10.30 a.m. on Tuesday, July 10, at the Board of Trade offices, Great George Street, London, S.W.1. Communications should be addressed to the secretary, Mr. E. W. Reardon, at that address.

A TOUR THROUGHOUT the Cornish minefields, arranged by the Institution of Mining and Metallurgy, has been completed, and Professor S. J. Truscott, President of the Institution, states that there are greater tin fields still to be worked there than there are in Bolivia. The present production level in Malaya, Professor Truscott adds, cannot be maintained indefinitely, and as soon as it begins to fall off there will again be a demand for tin from Cornwall.

IT IS REPORTED from Amsterdam that a new group has been formed in the tinplate industry by the merger of the interests of M. Woud, the former managing director of the United Tinplate Factories of Amsterdam, and the Dordtrechtsche metal ware factories. The United Tinplate Factories will consequently be competitors of the new group. The new company it is stated will be called the Bekkers Woud Metal Ware Factories. A new factory will be built near Amsterdam.

THE SUB-COMMITTEE of the National Federated Electrical Association and the Electrical Trades Union announces wage reductions of from ¼d. to ¾d. per hour, according to grade, based on a cost of living index. The new rates are 1s. 9½d. for Grade A, which includes travelling allowance, 1s. 7¼d. for Grade B, 1s. 6d. for Grade C, and 1s. 4½d. for Grade D. They operate as from the second pay day in June, and will remain current up to the first pay day in October.

THE EDWARD MEDAL has been awarded to Thomas Bourton and Thomas Philip Evans for gallantry at the blast furnaces of the Ebbw Vale Steel, Iron & Coal Company, Limited, on December 30 last. Two men who were cleaning a three-foot pipe connecting two boilers were overcome by carbon-monoxide gas. The relief discovered the body of one of the workmen, and Bourton and Evans entered the pipe and rescued the other at grave risk to themselves. Unfortunately the rescued workman died.

THE EXECUTIVES OF THE UNIONS which constitute the Engineering and Shipbuilding Trades Federation, have accepted the offer of the employers to increase the bonus on basis wages by 3s. to 10s. weekly. Six of the craft unions concerned with the shipbuilding industry which are not members of the federation are acting separately, and have asked for further consideration of their demand for an improved offer. The federation's acceptance implies the appointment of a joint committee to investigate the possibility of fixing an index wage figure from which there shall be future variations according to the state of the industry.

MR. R. V. LAMING, O.B.E., in his Report on the economic conditions in the Netherlands during 1927, states that the operation of the blast furnaces was not unsatisfactory, although no dividend was distributed. Co-operation continues with the German rolling mills, in which the Dutch blast-furnaces are interested to a considerable extent, notwithstanding the fact that these mills, the Phœnix, have joined the Rheinische Stahlwerke. It is stated that in the course of the year the Netherlands blast-furnaces imported 400,000 tons of ore, against 200,000 tons in the previous year. Since September they have been working at full capacity.

AN EXTRAORDINARY GENERAL MEETING of Messrs. W. & T. Avery, Limited, was held at Birmingham on Friday last for the purpose of considering a resolution authorising the capitalisation of £225,486 of the internal reserve fund and the distribution among the holders of the issued ordinary shares of one new ordinary share of £1 for every two ordinary shares held. The directors have had under consideration for some time the desirability of bringing the capital of the company more into relation with the value of the company's assets and their earning capacity. Their intention is that the new shares shall be allotted before the annual meeting in July, and that they shall rank equally with the old ordinary shares for the final dividend for the year ended March 31, 1928. The directors hope to recommend a final dividend of 10 per cent., making 15 per cent. for the year, on all the ordinary shares. The resolution was passed unanimously.

Personal Paragraphs.

MR. W. BERRYMAN has been appointed managing director of the United Flexible Metallic Tubing Company, Limited.

MR. H. J. YOUNG, F.I.C., the well-known consulting metallurgist, is at present confined to his room with a severe attack of pleurisy.

MR. HENRY A. GREAVES, one of the inventors of the Greaves-Etchells electric furnace and a director of Messrs. Watsons (Metallurgists), Limited, Lancaster Street, Sheffield, is now on a business trip to Russia.

Wills.

HARRISON, A. W., of Sunderland, formerly manager of Messrs. Richardsons, Westgarth & Company's marine engine works, Sunderland £23,996

LEARMOUTH, J., managing director of the Planet Foundries Company, Limited, Manchester, and Vice-Chairman of the National Light Castings Association ... £39,077

Contracts Open.

Bulawayo, July 24.—13,380 lineal ft. double hessian wrapped steel spigot and socket piping, 6-in., 4-in. and 3-in. internal diameter; 41 sluice valves, two scour valves, two air valves, seven hydrants, 52 cast-iron surface boxes and a quantity of cast-iron specials, for the Municipality of Bulawayo. Department of Overseas Trade, 35, Old Queen Street, London, S.W.1. (Reference A.X. 6277.)

Johannesburg, July 19.—Supply and delivery of structural steelwork, for the South African Railways and Harbours. Department of Overseas Trade. (Reference A.X. 6373.)

Johannesburg, June 23.—300 2½-in. hydrants, cast-iron bodies, and 280 sluice valves with socket ends, for the Town Council of Johannesburg. Department of Overseas Trade. (Reference A.X. 6350.)

London, S.W., June 19.—Girder bridge spans of 8½, 10, 20, 30 and 40 ft. (approximate total tonnage 213); and five footbridges (75-ft. centres of stairways), complete with stairways and roof coverings (approximate total tonnage 160), for the Madras and Southern Mahratta Railway Company, Limited. The company's offices, 25, Buckingham Palace Road, Westminster, S.W. (Fee £1 1s., not returnable.)

Sunderland, June 28.—100 tons of steel tramway rails. The General Manager and Engineer, Tramways Offices, Monkwearmouth, Sunderland.

Reports and Dividends.

Whitehaven Hematite Iron & Steel Company, Limited.—Loss for year ended March 31 of £13,854.

Stanton Ironworks Company, Limited.—Final dividend of 6 per cent., tax free, making 10 per cent. for the year.

Canadian Car and Foundry Company (England), Limited.—Dividend of 1¾ per cent. on preference stock for quarter ending June 30, 1928.

Richard Johnson, Clapham & Morris, Limited.—Net profit, £2,678; brought forward, £13,824; carried forward, £12,543; no ordinary dividend.

Cape Asbestos Company, Limited.—Profit for 1927, £39,705; brought in, £11,757; to reserve fund, £15,000; to staff benefit fund, £3,000; ordinary dividend, 12½ per cent.; carried forward, £11,862.

Lancashire and Yorkshire Waggon Company, Limited.—Net profit, £12,822; brought in, £12,591; to general reserve, £2,500; dividend of 12s. per share, less tax, making 10 per cent., less tax; carried forward, £14,913.

Electric Construction Company, Limited.—Net profit, after providing for debenture interest and depreciation, £20,593; brought forward, £14,345; final ordinary dividend at rate of 9 per cent. per annum, making 7½ per cent. for year; carried forward, £8,044.

Ruston & Hornsby, Limited.—Balance of profit and loss account, £141,856; depreciation, £42,009; interest on debentures and debenture stock, £26,750; brought in, £25,810; one year's dividend on 5 and 6 per cent. preference shares, £23,500; dividend of 2½ per cent. on ordinary shares, less tax, £51,250; carried forward, £24,157.

New Companies.

Farris & Farris, Limited, 76, Finsbury Pavement, London, E.C.2.—Capital £1,000. Iron, steel and brass merchants, etc. Directors: E. H. Farris and L. S. E. Farris.

United Brassfounders, Coppersmiths and Engineering Company, Limited, United Works, Walker Street, Hull.—Capital £500. Directors: A. Green, J. W. Grubb and R. A. Mackley.

Variable Power Transmissions, Limited, 7-8, Poultry, London, E.C.2.—Capital £30,000 in 25,000 8 per cent. non-cumulative preference shares of £1 and 100,000 ordinary shares of 1s., to acquire from F. J. Healey certain letters patent. Mechanical engineers, etc.

Monel-Weir, Limited.—Capital £10,000 in £1 shares. Manufacturers of and dealers in the special alloy of nickel and copper, known as monel-metal, steel, iron, brass, copper, and other metals and alloys, etc. Subscribers: Lord Weir and J. G. Weir. Solicitors: McClure, Naismith, Brodie & Company, Glasgow.

Pretoria Iron and Steel Works.—A member of the Ministry of the South African Union has denied a report recently published that only German engineers were to be employed and German machinery used in the erection of the new iron and steel works at Pretoria. The Minister adds that public tenders would be issued for the equipment of the new works. Nothing was said about the raising of the capital in London or about the selection of consulting engineers to the scheme.

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VOLATILE	,, ,,	1 %
MOISTURE	under	1·50%

Iron and Steel Markets.

Pig-Iron.

MIDDLESBROUGH.—Conditions in the Cleveland iron market still remain at the same level so often recorded in these reports, with little or no prospect of immediate relief from the monotony of slow demand and continued restricted production at the limited number of Tees-side furnaces now in operation. The one redeeming feature of the position is that stocks are small and are not increasing, and the warning to consumers is oft repeated—though still unheeded—that a sudden demand would create a shortage. On the export side, pig-iron shipments from the Tees fell from 20,427 tons in April to 16,351 tons in May, the decline being almost entirely in the coastwise shipments. For nearly three months now prices, both for home and export, have remained unaltered as follow:—No. 1 Cleveland foundry iron, 68s. 6d. per ton; No. 3 G.M.B., 66s.; No. 4 foundry, 65s.; and No. 4 forge iron, 64s. 6d. per ton.

With only a limited demand for home consumption, and indifference on the part of foreign buyers, the position in the East Coast hematite market continues disappointing, and from all accounts will shortly result in a further diminution of production. Meantime prices are nominally unchanged at 70s. per ton for mixed numbers, but offers at 69s. are frequently mentioned. On the North-West Coast Bessemer mixed numbers are still quoted at 70s. per ton at furnace.

LANCASHIRE.—Inquiries in the local markets for foundry pig reflect so far little improvement in bulk, but a slightly more active business is passing for prompt deliveries, with prices generally firm. Staffordshire and Derbyshire No. 3 foundry are still offered for local delivery at from 70s. to 71s. per ton, with Scottish equal qualities from 87s. 6d. to 90s. per ton, according to brand. As a rule, only small parcels are disposed of at present, consumers still pursuing the policy of hand-to-mouth buying pending a definite prospect of better times for the foundry industry.

THE MIDLANDS.—Throughout the Black Country area ironfounders still complain of the sluggishness in trade and many of them are not at all anxious to book orders ahead. For ordinary parcels Derbyshire is quoted at 61s. to 62s., and Northampton from 56s. to 57s. at the furnaces. North Staffordshire No. 3 is at 63s., but this price cannot hold in view of the competition from other fields.

SCOTLAND.—Little improvement can yet be observed in the outlook for foundry pig in the Scottish markets, consumers still hesitating to place forward business until a more active demand for castings is in sight, but prices remain unchanged, with No. 3 quality quoted nominally at 70s. f.o.t. furnaces.

Finished Iron.

Orders for marked bars are reported at Birmingham to be a little more plentiful at the present time, but there is no big tonnage being offered and the mills remain only moderately employed. The Association price of £12 at makers' works is unaltered. In regard to crown iron, the conditions remain very difficult, bulk business orders are absent entirely, and there is very keen competition for the meagre amount of business developing. Prices continue to vary from £9 to £9 15s. for this grade, and nut and bolt quality is round about £8 15s. per ton. Very little support is possible in connection with the latter quality, as the foreign product, in spite of the recent firming up in price, still shows a big disparity.

Steel.

At Sheffield a rather more hopeful view of the staple industry is now entertained in trade circles, though it is freely admitted that a much more substantial improvement is essential before a full recovery can be assured. The fact of rising Continental prices is largely responsible for the better outlook. Basic billets are selling slightly more freely, and business in acid billets is fairly active. Wire rod business continues quiet. Quotations:—Basic billets: Soft, £6 5s.; semi-hard, £7; medium, £7 2s. 6d.; hard, £7 12s. 6d.; soft basic wire rods, £7 10s.; acid ditto, £13 10s. The condition of the tinplate market is unchanged. The tone continues to be firm, and a fair volume of business has been done during the week. Most works have good order books, and are inclined to advance their prices.

Scrap.

Reports from the chief centres of the foundry metal scrap trade are somewhat unequal, but generally there appears to be a fairly steady demand on the part of consumers, with prices mostly unchanged, but firm. In the Midlands, although many of the foundries are not busy, merchants have no difficulty in disposing of the whole of their supplies of cast-iron scrap. For heavy machinery cast-iron scrap, broken into cupola sizes, 65s. per ton delivered is realised without difficulty, and 55s. per ton delivered for light cast-iron scrap. In Scotland it is difficult still to find outlets for first-class machinery scrap, even at 67s. 6d. per ton, and for heavy ordinary cast-iron scrap 61s. 3d. to 62s. 6d. per ton. Old cast-iron railway chairs are around 65s. to 67s. 6d. per ton, good, clean heavy turnings are 53s. 6d. to 55s. per ton, cast-iron borings are 52s. 6d. to 53s. 6d. per ton, and light cast-iron scrap is 56s. 3d. The above prices are all per ton, delivered f.o.t. consumers' works.

Metals.

Copper.—Due, doubtless, to seasonal influences, the market for warrant copper has been less active of late, though so far without any adverse effect upon current values. The continued strength of quotations may be attributable to the very general impression that a temporary shortage of metal for immediate deliveries has to be faced, and this is particularly so in the case of electrolytic, which has been in exceptional demand recently. American reports indicate very little easing off in the demand on that side of the Atlantic, and as the bulk of the business being placed is for June, metal stocks are necessarily at a very low ebb and prices are accordingly firm.

Closing quotations are:—

Cash.—Thursday, £64 6s. 3d. to £64 7s. 6d.; Friday, £64 3s. 9d. to £64 5s.; Monday, £64 6s. 3d. to £64 7s. 6d.; Tuesday, £64 3s. 9d. to £64 5s.; Wednesday, £63 18s. 9d. to £64.

Three Months.—Thursday, £64 6s. 3d. to £64 7s. 6d.; Friday, £64 3s. 9d. to £64 5s. 9d.; Monday, £64 6s. 3d. to £64 7s. 6d.; Tuesday, £64 3s. 9d. to £64 5s.; Wednesday, £63 17s. 6d. to £63 18s. 9d.

Tin.—As foreshadowed in last week's report, values of standard tin for cash have experienced a further relapse, and the market still remains dull and depressed. A closer examination of the statistical position showing an increase of over 2,000 tons in visible supplies was, of course, alone sufficient to cause a considerable depression, and conditions are unlikely to develop any radical change until such time as the anticipated increase in the demand from tinplate makers and other consumers materialises.

Official closing prices:—

Cash.—Thursday, £225 12s. 6d. to £225 15s.; Friday, £223 15s. to £223 17s. 6d.; Monday, £222 2s. 6d. to £222 5s.; Tuesday, £222 5s. to £222 7s. 6d.; Wednesday, £217 10s. to £217 12s. 6d.

Three Months.—Thursday, £224 15s. to £224 17s. 6d.; Friday, £223 to £223 5s.; Monday, £220 15s. to £221; Tuesday, £220 10s. to £220 12s. 6d.; Wednesday, £216 to £216 5s.

Spelter.—Business in this section of the metal markets continues uneventful, but prices are steadily maintained at the previous week's levels. From the producers' viewpoint, the future outlook is decidedly promising, for a steady advance in world consumption is revealed by the fact that, in spite of a constantly increasing output, there seems little tendency for stocks to accumulate.

Ordinary.—Thursday, £25 17s. 6d.; Friday, £25 15s. 3d.; Monday, £25 17s. 6d.; Tuesday, £25 17s. 6d.; Wednesday, £25 15s.

Lead.—The demand for soft foreign pig of late having developed a slightly more active tendency, home consumers are now covering their requirements on a rather more generous scale than formerly. Arrivals of metal are still very limited, and this may result in a further appreciation of values, although it seems probable that the advance already registered will prove to be an adequate representation of the market's strengthened position.

Closing prices:—

Soft Foreign (Prompt).—Thursday, £21 8s. 9d.; Friday, £21 6s. 3d.; Monday, £21 7s. 6d.; Tuesday, £21 5s.; Wednesday, £21.

Correspondence.

[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]

"Studying Journeys."

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—In your issue of June 7 you describe the visits of students of Paris Foundry High Schools to various French steel works and foundries, and express the hope that the British universities and technical colleges will organise similar works visits during the long vacation. In fairness to the British metallurgical schools it should be stated that this plan has been adopted by some of our Universities for many years. At the University of Birmingham, works visits form an integral part of a student's training; he is required to spend a period of not less than three months in an approved works during his university course; this usually is done during the long vacation. In addition, excursions to works in the Midlands are organised during the winter and spring term by the Students' Metallurgical Society; fourteen such visits have been arranged during the present session to local metallurgical and engineering works. Visits are also arranged in other metallurgical centres, on the same lines as those organised for the French students; during the last Easter vacation a large party of Birmingham students spent a week in the Swansea district, visiting six works and Swansea University College. Visits of this kind are also arranged from time to time in metallurgical centres abroad. I think, therefore, that we may claim that this important aspect of education of our young metallurgists is not entirely neglected in this country.—Yours, etc.,

D. HANSON.

Department of Metallurgy,
The University, Edgbaston,
Birmingham.

Manganese Sulphur Ratio in Malleable Cast Iron.

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—I have read with considerable interest Mr. Hurren's Paper on "Malleable Iron," published in a recent issue of the Journal. As is usual with Mr. Hurren's Papers, it contains very useful and interesting information.

His "low manganese theory" in regard to the cracking of malleable castings is of particular interest to me, as I have encountered similar experience in this direction, in connection with the manufacture of black-heart malleable.

In the Paper the author says, in concluding his views on cracking, "The idea is postulated as a possible explanation of the trouble," and "but it is a curious fact that so far as at present can be said, any tendency for cracks to develop during annealing ceased when the manganese content was raised." Now I am sure Mr. Hurren will be interested to learn that his views and theory on cracking can be substantiated by other practical experience in this country.

I had brought to my knowledge some time ago that a firm who were making blackheart malleable castings encountered intermittently the trouble of castings cracking during annealing. The matter was thoroughly investigated, and it was proved beyond doubt that in the majority of cases cracked castings could be traced to low manganese metal, or—to be more explicit—the manganese content was less in amount than was required *theoretically* to balance the sulphur present. I have stated "required theoretically," because in the discussion following the Paper, Mr. A. E. Peace stated that "No one yet had been able to produce manganese-sulphide in the presence of iron in theoretical quantities"; whilst this may be true, I can say definitely that if the manganese in the metal is consistently below the amount required to balance the sulphur, an epidemic of cracked castings will arise and that the epidemic will surely die out if the manganese is raised to, or slightly above, the balancing amount.

In regard to the sulphur manganese ratio of 1 : 7, I would mention that it is better to add manganese equal to not less than double the sulphur content.—Yours, etc.,

H. H. SHEPHERD.

117, Foxhall Road, Ipswich.

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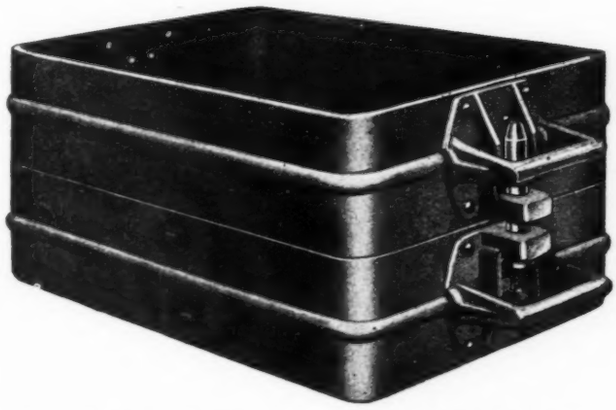

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WEEKLY PRICE CURRENT.

COPPER.

	£ s. d.
Standard cash	63 18 9
Three months	63 17 6
Electrolytic	69 0 0
Tough	67 0 0
Best selected	67 5 0
Sheets	94 0 0
India	77 5 0
Wire bars	69 0 0
Do. June	69 0 0
Do. July	69 0 0
Ingot bars	69 0 0
H.C. Wire rods	73 10 0
Off. av. cash, May	62 11 9 9/11
Do. 3 mths., May	62 15 8 2/11
Do., Sttlmnt., May	62 11 8 9/11
Do., Electro, May	67 9 3 3/11
Do., B.S., May	65 18 0 5/8
Aver. spot price, copper, May	62 11 9 1/4
Do., Wire bars, May	67 14 3 1/2
Solid drawn tubes	13½d.
Brazed tubes	13½d.
Wire	9½d.

BRASS.

Solid drawn tubes	11½d.
Brazed tubes	13½d.
Rods, drawn	10½d.
Rods, extd. or rlld.	7½d.
Sheets to 10 w.g.	10½d.
Wire	9½d.
Rolled metal	9½d.
Yellow metal rods	7½d.
Do. 4 × 4 Squares	8d.
Do. 4 × 3 Sheets	8½d.

TIN.

	£ s. d.
Standard cash	217 10 0
Three months	216 0 0
English	217 0 0
Bars	223 5 0
Straits	223 10 0
Australian	225 5 0
Eastern	223 15 0
Banca	Nominal
Off. av. cash, May	230 19 3 3/11
Do., 3 mths., May	230 7 10 1/2
Do., Sttlmt., May	230 18 7 7/11
Aver. spot, May	230 19 3

SPELTER.

	£ s. d.
Ordinary	25 15 0
Remelted	25 0 0
Hard	20 7 6
Electro 99.9	30 0 0
English	26 5 0
India	21 10 0
Zinc dust	33 0 0
Zinc ashes	8 0 0
Off. aver., May	25 18 6 5/11
Aver., spot, May	26 2 0½

LEAD.

	£ s. d.
Soft foreign ppt.	21 0 0
English	22 10 0
Off. average, May	20 12 11 5/11
Average spot, May	20 9 8

ZINC SHEETS, &c.

	£ s. d.
Zinc sheets, English	33 15 0
Do. V.M. ex whf.	32 5 0
Rods	39 0 0
Boiler plates	29 10 0
Battery plates	31 5 0

ANTIMONY.

	£ s. d.
Special brands, Eng.	59 10 0
Chinese	40 10 0
Crude	34 10 0

QUICKSILVER.

	£ s. d.
Quicksilver	22 2 6

FERRO-ALLOYS AND STEEL-MAKING METALS.

	£ s. d.
Ferro-silicon—	
25%	8 0 0
45/50%	13 2 0
75%	20 10 0
Ferro-vanadium—	
35/40%	14/3 lb. Va.
Ferro-molybdenum—	
70/75% c. free	4/6 lb. Mo.
Ferro-titanium—	
23/25% carbonless	1/2 lb.
Ferro-phosphorus, 20/25%	£18 2 6
Ferro-tungsten—	
80/85%, c. fr.	1/3½ lb.
Tungsten metal powder—	
98/99%	1/7½ lb.
Ferro-chrome—	
2/4% car.	£32 0 0
4/6% car.	£22 2 6
6/8% car.	£21 12 6
8/10% car.	£21 5 0
Ferro-chrome—	
Max. 2% car.	£34 10 0
Max. 1% car.	£39 12 6
Max. 0.70% car.	£45 10 0
70% carbonless	1/2 lb.
Nickel—99% cubes or pellets	£175 0 0
Ferro-cobalt	9/6 lb.
Aluminium 98/99%	£105 0 0
Metallic chromium—	
96/98%	2/8 lb.
Ferro-manganese (net)—	
76/80% loose	£13 10 0
76/80% packed	£14 10 0
76/80% export	£13 5 0
Metallic manganese—	
94/96% carbonless	1/6 lb.

Per ton unless otherwise stated.

HIGH-SPEED TOOL STEEL.

Finished bars, 14% tungsten	£0 2 3
Finished bars, 18% tungsten	£0 2 9

Per lb. net, d/d buyers' works.

Extras—	
Rounds and squares, 3 in. and over	4d. lb.
Rounds and squares, under ½ in. to ¼ in.	3d. lb.
Do., under ¼ in. to 1/8 in.	1/- lb.
Flats, ½ in. × ¼ in. to under 1 in. × ½ in.	3d. lb.
Do., under ½ in. × ¼ in.	1/- lb.
Bevels of approved sizes and sections	6d. lb.

Bars cut to length, 10% extra.

Scrap from high-speed tool steel—	
Scrap pieces	3d.
Turnings and swarf	1d.

Per lb. net, d/d steel makers' works.

SCRAP.

	£ s. d.	£ s. d.
South Wales—		
Hvy. steel	3 7 6 to 3 10 0	
Bundled steel and shrngs.	3 1 0 to 3 7 6	
Mixed iron and steel	3 0 0 to 3 2 6	
Heavy cast iron	3 0 0	
Good machinery for foundries	3 5 0	
Cleveland—		
Heavy steel	2 17 0	
Steel turnings	2 8 6	
Cast iron borings	2 3 0	
Heavy forge	3 10 0	
Bushelled scrap	3 2 6	
Cast-iron scrap	3 2 0 to 3 6 0	
Lancashire—		
Cast-iron scrap	3 5 0	
Hvy. wrought	3 2 6	
Steel turnings	2 2 6	
London—Merchants' buying prices delivered yard.		
Copper (clean)	53 0 0	
Brass	38 0 0	
Lead (less usual draft)	18 10 0	
Tea lead	16 10 0	
Zinc	16 10 0	
New aluminium cuttings	70 0 0	
Braziery copper	48 0 0	
Gunmetal	49 0 0	
Hollow pewter	160 0 0	
Shaped black pewter	115 0 0	

PIG-IRON.

(f.o.t. unless otherwise stated.)

N.E. Coast—	
Foundry No. 1	68/6
Foundry No. 3	66/-
Foundry No. 4	65/-
Forge No. 4	64/6
Hematite No. 1	69/6
Hematite M/Nos.	69/-
N.W. Coast—	
Hem. M/Nos. d/d Glas.	80/-
,, d/d Birm.	86/-
Midlands—	
Staffs. common*	70/-
,, No. 4 forge	57/6
,, No. 3 fdry.	62/-
Shrops. basic	—
,, Cold blast, ord.*	—
,, ,, roll iron*	—
* d/d Birmingham.	
Northants forge	52/6
,, fdry. No. 3	56/6
Derbyshire forge	58/-
,, fdry. No. 3	63/-
,, basic	—
Scotland—	
Foundry No. 1	75/-
,, No. 3	70/-
Hem. M/Nos.	74/-
Sheffield (d/d district)—	
Derby forge	64/-
,, fdry. No. 3	66/6
Lincs. forge	66/6
,, fdry. No. 3	67/-
E.C. hematite	82/6
W.C. hematite	85/6
Lincs. (at furnaces)—	
Forge No. 4	62/-
Foundry No. 3	62/6
Basic	60/6
Lancashire (d/d eq. Man.)—	
Derby forge	—
,, fdry. No. 3	71/3
Northants foundry No. 3	—
Dalzell, (ordinary)	87/6 to 90/-
Summerlee, No. 3	87/6
Glengarnock, No. 3	87/6
Gartsherrie, No. 3	87/6
Monkland, No. 3	—
Shotts, No. 3	87/6

FINISHED IRON AND STEEL.

Usual District deliveries for iron; delivered consumers' station for steel.

Iron—	£ s. d.	£ s. d.
Bars (cr.) nom.	9 0 0 to 10 15 0	
Nut and bolt iron	8 15 0	
Hoops	11 10 0	
Marked bars (Staffs.) f.o.t.	12 0 0	
Gas strip	11 10 0	
Bolts and nuts, ½ in. × 4 in.	15 0 0	
Steel—		
Ship plates	8 7 6	
Boiler plts.	10 10 0	
Chequer plts.	10 12 6	
Angles	7 17 6	
Tees	8 17 6	
Joists	7 17 6	
Rounds and squares, 3 in. to 5½ in.	8 17 6	
Rounds under 3 in. to ½ in. (Untested)	7 15 0	
	and upwards	
Flats, over 5 in. wide and up	8 7 6	
Flats, 5 in. to 1½ in.	7 17 6	
Rails, heavy	8 2 6 to 8 10 0	
Fishplates	12 10 0	
Hoops (Staffs.)	10 0 0	
Black sheets, 24g.	10 0 0	
Galv. cor. shts., 24g.	13 7 6	
Galv. fencing wire 8g. plain	12 10 0	
Billets, soft	6 5 0 to 6 15 0	
Billets, hard	7 2 6 to 7 12 6	
Sheet bars	6 0 0	
Tin bars	6 0 0	

PHOSPHOR BRONZE.

	Per lb. basis.
Strip	1 2½
Sheet to 10 w.g.	1 3
Wire	1 3½
Rods	1 3
Tubes	1 8½
Castings	1 2

Delivery 3 cwt. free.
10% phos. cop. £40 above B.S.
15% phos. cop. £50 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. CLIFFORD & SON, LIMITED.

NICKEL SILVER, &c.

	per lb.
Ingots for raising	9d. to 1/3
Rolled—	
To 9 in. wide	1/3 to 1/9
To 12 in. wide	1/3½ to 1/9½
To 15 in. wide	1/3½ to 1/9½
To 18 in. wide	1/4 to 1/10
To 21 in. wide	1/4½ to 1/10½
To 25 in. wide	1/5 to 1/11
Ingots for spoons and forks	9d. to 1/5½
Ingots rolled to spoon size	1/- to 1/8½
Wire round—	
3/0 to 10 G.	1/6½ to 2/1½

with extras according to gauge.

AMERICAN IRON AND STEEL.

At Pittsburgh unless otherwise stated.

	Dols.
No. 2X foundry, Phila.	20.76
No. 2 foundry, Valley	17.00
No. 2 foundry, Birm.	15.50
Basic	17.76
Bessemer	18.76
Malleable	19.01
Grey forge	18.26
Ferro-mang. 80% d/d	105.00
O.-h. rails, h'y at mill	43.00
Bess billets	33.00
O.-h. billets	33.00
O.-h. sheet bars	34.00
Wire rods	44.00
	Cents.
Iron bars, Phila.	2.12
Steel bars	1.85
Tank plates	1.85
Beams, etc.	1.85
Skelp, grooved steel	1.85
Skelp, sheared steel	1.85
Steel hoops	2.20
Sheets, black, No. 24	2.70
Sheets, galv., No. 24	3.55
Sheets, blue an'l'd., 9 and 10	2.00
Wire nails	2.55
Plain wire	2.50
Barbed wire, galv.	3.35
Tinplates, 100 lb. box	$5.25

COKE (at ovens).

Welsh foundry	—
,, furnace	—
Durham and North.	
,, foundry	14/- to 14/6
,, furnace	14/-
Other Districts, foundry	—
,, ,, furnace (basis)	12/- to 13/-

TINPLATES.

f.o.b. Bristol Channel ports.

I.C. Cokes	20×14	box	18/7½
,,	28×20	,,	37/3
,,	20×10	,,	27/3
,,	18½×14	,,	19/3
C.W.	20×14	,,	17/3
,,	28×20	,,	34/6
,,	20×10	,,	22/-
,,	18½×14	,,	15/9
Terneplates	28×20		34/- per box basis f.o.b.

SWEDISH IRON.

Bars, hammered, £17 10 0 to £18 10 0	
Rolled Ord.	£15 0 0 to £15 10 0
Nail rods	£15 7 6 to £15 15 0
Keg. steel nom.	£33 to £35
Faggot steel nom.	£22 to £25
Blooms, according to quality	£8 to £12
Pig-iron	£5 15 0 to £6 0 0

all f.o.b. Gothenburg.

TUBES AND FITTINGS.

Up to and incl. 6 in.

	Tubes.	*Fittings.*
Gas	67½%	50%
Water	63½%	45%
Steam	60%	40%

W.I. 10% extra.

DAILY FLUCTUATIONS.

Standard Copper (cash).

	£	s.	d.		
June 7 ..	64	6	3	inc.	3/9
,, 8 ..	64	3	9	dec.	2/6
,, 11 ..	64	6	3	inc.	2/6
,, 12 ..	64	3	9	dec.	2/6
,, 13 ..	63	18	9	,,	5/-

Electrolytic Copper.

	£	s.	d.		
June 7 ..	68	15	0	No change	
,, 8 ..	68	15	0	,, ,,	
,, 11 ..	69	0	0	inc.	5/-
,, 12 ..	69	0	0	No change	
,, 13 ..	69	0	0	,, ,,	

Standard Tin (cash).

	£	s.	d.		
June 7 ..	225	12	6	inc.	50/-
,, 8 ..	223	15	0	dec.	37/6
,, 11 ..	222	2	6	,,	32/6
,, 12 ..	222	5	0	inc.	2/6
,, 13 ..	217	10	0	dec.	95/-

Tin (English ingots).

	£	s.	d.		
June 7 ..	224	15	0	inc.	40/-
,, 8 ..	222	15	0	dec.	40/-
,, 11 ..	221	5	0	,,	30/-
,, 12 ..	221	5	0	No change	
,, 13 ..	217	0	0	dec.	85/-

Zinc Sheets (English).

	£	s.	d.	
June 7 ..	33	15	0	No change
,, 8 ..	33	15	0	,, ,,
,, 11 ..	33	15	0	,, ,,
,, 12 ..	33	15	0	,, ,,
,, 13 ..	33	15	0	,, ,,

Spelter (ordinary).

	£	s.	d.	
June 7 ..	25	17	6	No change
,, 8 ..	25	16	3	dec. 1/3
,, 11 ..	25	17	6	inc. 1/3
,, 12 ..	25	17	6	No change
,, 12 ..	25	15	0	dec. 2/6

Lead (English).

	£	s.	d.	
June 7 ..	22	15	0	No change
,, 8 ..	22	15	0	,, ,,
,, 11 ..	22	15	0	,, ,,
,, 12 ..	22	15	0	,, ,,
,, 13 ..	22	10	0	dec. 5/-

AVERAGE MONTHLY PRICES OF MARKED BARS (SOUTH STAFFS).

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1897 ...	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0
1898 ...	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	8 0 0	8 0 0	7 11 8
1899 ...	8 0 0	8 0 0	8 0 0	8 0 0	8 10 0	8 10 0	9 0 0	9 0 0	9 10 0	10 0 0	10 0 0	10 0 0	8 3 4
1900 ...	11 0 0	11 10 0	11 10 0	11 10 0	11 10 0	11 10 0	11 10 0	11 10 0	11 10 0	11 10 0	11 10 0	11 10 0	11 5 10
1901 ...	9 10 0	9 10 0	9 10 0	9 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 16 8
1902 ...	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 5 0	8 5 0	8 5 0	8 5 0	8 5 0	8 5 0	8 7 6
1903 ...	8 5 0	8 5 0	8 5 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 8 9
1904 ...	8 10 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 10
1905 ...	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 10 0	8 10 0	8 1 8
1906 ...	8 10 0	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0	8 10 0	8 10 0	8 10 0	8 10 0	9 0 0	8 15 10
1907 ...	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0
1908 ...	9 0 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 5 10
1909 ...	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0
1910 ...	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0
1911 ...	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0
1912 ...	8 10 0	8 10 0	8 10 0	8 15 0	9 0 0	9 0 0	9 0 0	9 8 0	9 10 0	9 10 0	9 10 0	9 15 0	9 1 6
1913 ...	10 0 0	10 0 0	10 0 0	10 0 0	10 0 0	10 0 0	10 0 0	9 10 0	9 10 0	9 4 0	9 0 0	9 0 0	9 13 8
1914 ...	8 12 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0	8 14 4
1915 ...	9 0 0	9 0 0	9 3 0	10 2 0	10 15 0	11 10 0	12 0 0	12 0 0	12 0 0	12 7 6	12 10 0	13 10 0	11 5 0
1916 ...	13 10 0	13 10 0	14 13 0	15 0 0	15 0 0	15 0 0	15 0 0	15 10 0	15 10 0	15 0 0	15 10 0	15 0 0	14 18 7
1917 ...	15 10 0	15 10 0	15 10 0	15 10 0	15 10 0	15 10 0	15 10 0	15 10 0	15 10 0	15 10 0	15 10 0	15 10 0	15 10 0
1918 ...	15 12 6	16 0 0	16 0 0	16 0 0	16 0 0	16 0 0	16 0 0	16 0 0	16 0 0	17 0 0	17 0 0	17 0 0	16 6 3
1919 ...	18 0 0	18 10 0	20 0 0	20 0 0	23 0 0	23 0 0	23 0 0	24 12 0	25 0 0	25 0 0	25 0 0	25 5 0	22 10 7
1920 ...	26 17 6	27 0 0	28 0 0	30 5 0	30 10 0	33 10 0	33 10 0	33 10 0	33 10 0	33 10 0	33 10 0	33 10 0	31 10 2
1921 ...	31 10 0	30 3 4	27 10 0	27 10 0	27 10 0	24 15 0	21 0 0	20 0 0	20 0 0	17 10 0	17 0 0	16 0 0	23 7 4
1922 ...	16 0 0	14 17 6	14 10 0	13 10 0	13 10 0	13 10 0	13 10 0	13 10 0	13 10 0	13 10 0	13 10 0	13 10 0	13 18 1½
1923 ...	13 10 0	13 10 0	13 16 0	14 7 6	14 10 0	14 10 0	14 10 0	14 10 0	14 10 0	14 10 0	14 10 0	14 10 0	14 5 3½
1924 ...	14 10 0	14 10 0	14 10 0	15 0 0	15 0 0	15 0 0	15 0 0	15 0 0	15 0 0	15 0 0	15 0 0	14 17 6	14 17 3½
1925 ...	15 0 0	15 0 0	15 0 0	15 0 0	15 0 0	14 10 0	14 10 0	14 10 0	14 10 0	14 10 0	14 10 0	14 0 0	14 13 4
1926 ...	14 0 0	14 0 0	14 0 0	14 0 0	14 0 0	14 0 0	14 0 0	14 0 0	14 0 0	14 0 0	—*	14 10 0	14 0 10
1927 ...	14 10 0	14 10 0	14 10 0	14 10 0	14 10 0	13 10 0	13 10 0	13 10 0	13 10 0	13 0 0	13 0 0	12 18 0	13 15 8
1928 ...	12 10 0	12 10 0	12 10 0	12 2 6	12 0 0	—	—	—	—	—	—	—	—

* No quotation available.

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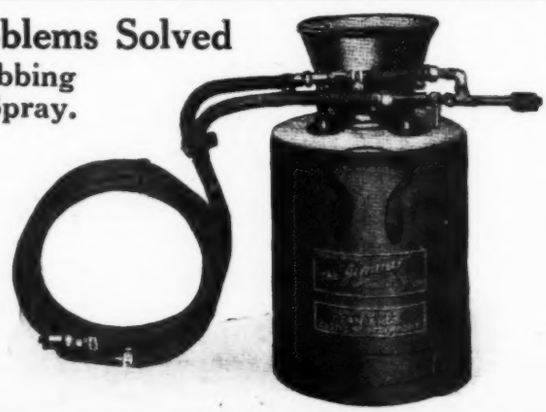
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